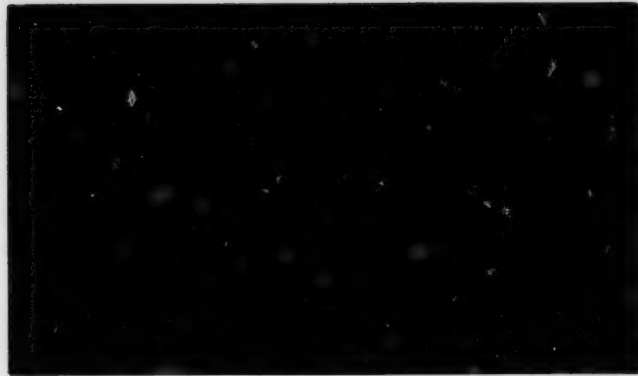




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**RADIONAVIGATION/LOCATION
REQUIREMENTS
FOR
SURFACE USERS IN CANADA:
PRESENT AND FUTURE**

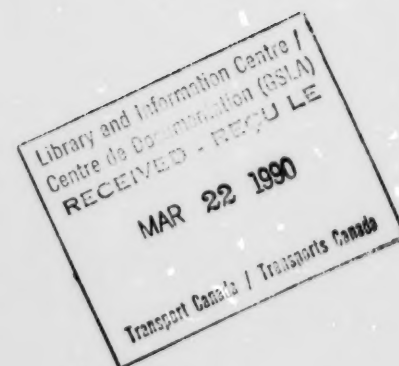
Prepared for:
Transportation Development Centre
Policy and Coordination Group
Transport Canada

November 1989

Submitted by:

J. Rostenne and David Deziel

THOMPSON-HICKLING AVIATION INC.



432230

The contents of this report reflect the views
of Thompson-Hickling Aviation Inc. and not
necessarily the official view or opinions of the
Transportation Development Centre of Transport Canada.

NOTE:

Un sommaire en français de ce rapport est inclus avant la table des matières.



1. Transport Canada Publication No. TP 9452E	2. Project No. 6931	3. Recipient's Catalogue No.		
4. Title and Subtitle Radionavigation/Location Requirements for Surface Users in Canada: Present and Future		5. Publication Date November 1989		
		6. Performing Organization Document No. 1898		
7. Author(s) Jacques Rostenne, David Deziel		8. Transport Canada File No. 1455-192		
9. Performing Organization Name and Address Thompson-Hickling Aviation Inc. 50 O'Connor Street, Suite 402 Ottawa, Ontario K1P 6L2		10. DSS File No. 14SD.T8200-7-7513/A		
		11. DSS or Transport Canada Contract No. T8200-7-7513/01-SD		
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) Guy Favreau Complex 200 René Lévesque Blvd. West West Tower, Suite 601 Montreal, Quebec H2Z 1X4		13. Type of Publication and Period Covered Final		
		14. Project Officer Barry Myers		
15. Supplementary Notes (Funding programs, titles of related publications, etc.)				
16. Abstract This report describes work to prepare a description of surface users' requirements for radionavigation and to present an estimate of the present extent of users of radionavigation equipment as well as a forecast of extent of use by the year 2000. The study was structured as directed investigation rather than a sample survey to typify user needs and use patterns by sectors in a cost efficient way. The methodology comprised 5 phases: documentation review and expert interviews; development of interview guidelines; development of alternative radionavigation systems evolution scenarios; interviews with current and potential surface user groups and data synthesis. The study developed groupings for surface users and typified the needs for each group. User groups include: public service, goods movement, private, military, and other surface users. User needs were expressed in terms of functions required, coverage, accuracy, reliability, availability, and update rate. Present-use estimates were made in terms of number and types of devices per sector; forecasts are in terms of percentage of fleet or other relevant criteria, type of device and trends from 1988 to the year 2000. Radionavigation/location systems included in this report were grouped into three major types of systems: active satellite systems represented by the GEOSTAR example; passive satellite systems represented by the GPS example; and ground-based systems represented by the LORAN-C example.				
17. Key Words Radionavigation, location, LORAN-C, GPS, GEOSTAR, demand, forecast, sign posts, electronic, highway, off-road		18. Distribution Statement Limited number of copies available from the Transportation Development Centre		
19. Security Classification (of this publication) Unclassified	20. Security Classification (of this page) Unclassified	21. Declassification (date) —	22. No. of Pages xiv, 153	23. Price —

1. N° de la publication de Transports Canada TP 9452E		2. N° de l'étude 6931		3. N° de catalogue du destinataire	
4. Titre et sous-titre Radionavigation/Location Requirements for Surface Users in Canada: Present and Future				5. Date de la publication Novembre 1988	
				6. N° du document de l'organisme exécutant 1898	
7. Auteur(s) Jacques Rostenne, David Deziel				8. N° de dossier — Transports Canada 1455-192	
9. Nom et adresse de l'organisme exécutant Thompson-Hickling Aviation Inc. 50, rue O'Connor, suite 402 Ottawa (Ontario) K1P 6L2				10. N° de dossier — ASC 14SD.T8200-7-7513/A	
				11. N° de contrat — ASC ou Transports Canada T8200-7-7513/01-SD	
12. Nom et adresse de l'organisme parrain Centre de développement des transports (CDT) Complexe Guy-Favreau 200 ouest, boul. René-Lévesque Tour ouest, suite 601 Montréal (Québec) H2Z 1X4				13. Genre de publication et période visée Final	
				14. Agent de projet Barry Myers	
15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)					
16. Résumé Ce rapport décrit le travail réalisé pour préparer la description des exigences des utilisateurs terrestres, en termes de radionavigation et localisation et pour présenter un estimé de l'utilisation actuelle et en l'an 2000 des équipements de radionavigation et de localisation. L'étude a été structurée sur le modèle des recherches dirigées plutôt que sous la forme d'un sondage. L'objectif était d'établir des types d'utilisateurs de la façon la plus efficace et économique. La méthodologie comprenait les phases suivantes : révision de la documentation et interviews avec des experts; développement d'un guide d'interviews; développement de scénarios d'évaluation pour les systèmes de radionavigation et interviews avec des utilisateurs actuels et potentiels; et synthèse des données. L'étude a développé des regroupements d'utilisateurs terrestres et a établi leurs exigences typiques. Les groupes d'utilisateurs incluent : les services publics, le transport des marchandises, les utilisateurs privés, les forces armées et d'autres utilisateurs terrestres. Les exigences des utilisateurs ont été exprimées en termes de : fonctions requises, couverture, précision, fiabilité, disponibilité et fréquence de mises à jour. Les estimations courantes ont été faites en termes de nombres et de types d'équipement par secteur. Les prévisions sont faites en termes de pourcentage des véhicules ou autre critère approprié pour la période 1988-2000. Les systèmes de radionavigation/localisation inclus dans ce rapport ont été regroupés en satellites actifs du type GEOSTAR, satellites passifs du type GPS et systèmes terrestres du type LORAN-C.					
17. Mots clés Radionavigation, location, LORAN-C, GPS, GEOSTAR, demand, forecast, sign posts, electronic, highway, off-road			18. Diffusion Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.		
19. Classification de sécurité (de cette publication) Non classifiée	20. Classification de sécurité (de cette page) Non classifiée	21. Déclassification (date) —	22. Nombre de pages xiv, 153	23. Prix —	

SUMMARY

Radionavigation signals are available in Canada from domestic and foreign sources. In Canada they are provided by the Aviation Group and Marine Group of Transport Canada, the Department of National Defence and in some cases by provincial governments, private corporations and individuals.

Recently, cross-modal applications have received increased attention throughout the navigation community due to the emergence of new technologies capable of multi-modal application, the new requirements identified by surface users, and to the limits of the available frequency spectrum.

Several major initiatives have been undertaken recently in order to re-assess radionavigation technologies and their prospective applications. These include radionavigation plans being developed by Transport Canada's Aviation Group and the Marine Group in Canada as well as a federal radionavigation plan published by the Department of Defence and the Department of Transport in the U.S.

This report describes work by Thompson-Hickling Aviation Inc. for Transport Canada to prepare a description of surface user requirements for radionavigation and an estimate of the present extent of uses of radionavigation/location equipment by surface users as well as a forecast of extent of use by the year 2000. The study was structured as a directed investigation rather than a sample survey to typify user needs in a cost efficient way. The methodology comprised five phases: documentation review and expert interviews; interview guidelines development; development of alternative radionavigation systems evolution scenarios; interviews with current and potential ground surface users; and, data synthesis. Radionavigation systems development scenarios were the object of a number of in-depth interviews with specialists. Equipment suppliers were surveyed with respect to their equipment appropriate to ground surface use. The study developed a grouping for surface users and typified the needs for each group. User groups include: public service, goods movement, private, military, and other surface users. User needs were expressed in terms of: functions required, coverage, accuracy, reliability, availability, and update rate. Present-use estimates were made in terms of number and types of devices per sector; forecasts are in terms of percentage of fleet or other relevant criteria, type of device and trends from 1988 to the year 2000.

The present technology of navigation and location is not based solely on radionavigation devices. Many nonradionavigation systems do exist, some are utilized independently, some are integrated with radionavigation based systems (generally for redundancy and periodic "fix" purposes). Radionavigation devices are also integrated with radiocommunication systems. The focus of this study is, however, solely on radionavigation/location. For the purpose of review and description, radionavigation/location systems have been grouped as:

- Present surface-based radionavigation systems; LORAN-C, Doppler Radar, Nondirectional Beacons, Omega, Decca, proximity devices, radio frequency systems, Advanced Train Control Systems, Mobile Emergency Tracking systems, cellular, line 10 television system, VOR and TACAN systems.
- Present satellite-based radionavigation/location systems (GEOSTAR, SARSAT, COSPAS, RDSS, Fleet trak).

- **Future Systems (GPS, autoguide ARCS, IMMARSAT, MSAT, NAVSAT, AVSAT and GLONASS).**

The study also reviewed briefly some nonradionavigation systems often used in conjunction with radionavigation systems (dead reckoning, ETAK, VDO, EVA, CARIN, compass).

SOMMAIRE

Un certain nombre de signaux de radionavigation sont disponibles au Canada en provenance de sources domestiques et étrangères. Les signaux de navigation canadiens sont fournis par les groupes Aviation et Marine de Transports Canada, par le ministère de la Défense nationale et dans certains cas, par les gouvernements provinciaux ou même par des entreprises privées et des individus.

Les applications intermodales ont récemment attiré l'attention des utilisateurs de services de navigation à cause de l'introduction de nouvelles technologies capables d'être utilisées par plusieurs modes de transport, du fait que l'on a récemment identifié des besoins nouveaux de la part des utilisateurs de surface et aussi en fonction des limitations du nombre de radio fréquences disponibles.

Un nombre important de nouvelles initiatives ont été entreprises dans le but de réévaluer les technologies de radionavigation et leurs applications possibles. Ces efforts incluent les plans de radionavigation en développement par les groupes Aviation et Marine de Transports Canada, ainsi que les plans de radionavigation publiés par le ministère de la Défense nationale et par le Département des transports du gouvernement fédéral des Etats Unis.

Ce rapport contient une description des travaux entrepris par Thompson-Hickling Aviation Inc. pour le compte de Transports Canada, dans le but de préparer une description des besoins des utilisateurs de surface en termes de radionavigation et un estimé de l'étendue de l'utilisation actuelle d'équipements de radionavigation/localisation par les utilisateurs de surface, de même qu'une projection de leur utilisation à l'horizon de l'an 2000. Cette étude a été structurée sous forme de recherche dirigée, plutôt que sous forme d'étude par sondage, de façon à permettre l'élaboration plus économique des profils d'utilisateurs. La méthodologie utilisée comprenait cinq phases: revue de la documentation et interviews avec des experts; développement de guides d'interviews; développement des scénarios alternatifs de l'évolution des systèmes de radionavigation; interviews avec des utilisateurs de surface actuels et potentiels et synthèse des données. Le développement des scénarios d'évolution des systèmes de radionavigation/localisation a fait l'objet de nombreuses interviews en profondeur avec des spécialistes du domaine. Les fournisseurs d'équipements ont aussi été étudiés en ce qui concerne leurs équipements utilisables pour des fins de radionavigation de surface.

L'étude a développé un regroupement et des profils de besoins pour chaque type d'utilisateur de surface. Les groupes d'utilisation étudiés incluent: les services publics, le transport de marchandises, les utilisateurs privés, les forces armées ainsi que d'autres groupes d'utilisateurs. Les besoins des utilisateurs ont été exprimés en termes de: fonctions requises, couverture, précision, fiabilité, disponibilité et fréquence de mise à jour.

Les estimés et les prévisions d'utilisation suivent les regroupements établis dans la première partie de l'étude, incluant les services publics, le transport de marchandises, les utilisateurs privés, les forces armées ainsi que d'autres groupes d'utilisateurs.

Les estimés portant sur les volumes d'utilisation actuelle ont été exprimés en termes de nombres et de types d'instruments par secteur. Les prévisions sont exprimées en termes de pourcentage des véhicules du secteur ou autre critère approprié. Les tendances recouvrent la période 1988-2000.

La technologie courante de navigation et de localisation n'est pas seulement basée sur des systèmes de radionavigation, il existe plusieurs systèmes de navigation qui n'utilisent pas

d'ondes hertziennes. Ces systèmes sont utilisés soit indépendamment, soit intégrés avec des systèmes de radionavigation (pour des raisons de redondance ou pour permettre un calibrage périodique). Les systèmes de radionavigation sont aussi souvent intégrés avec des systèmes de radiocommunication. L'emphase de cette étude reste néanmoins circonscrite à la radionavigation/localisation. Dans le but de faciliter la description et l'évaluation des systèmes de radionavigation/localisation, nous les avons regroupés comme suit:

- Systèmes actuels de radionavigation de surface: LORAN-C, radar du type Doppler, faisceaux non-directionnels, Omega, Decca, instruments opérant à faible distance, systèmes AM et FM, systèmes de contrôle avancés d'opération ferroviaire, systèmes mobiles de repérage et suivi d'urgence, systèmes cellulaires, systèmes basés sur la ligne 10 des transmissions de TV, systèmes VOR et TACAN.

- Systèmes actuels de radionavigation/localisation basés sur satellites: GEOSTAR, SARSAT, COSPAS, RDSS, Fleet track).

- Systèmes futurs (GPS, autoguide, ARCS, IMMARSAT, MSAT, NAVSAT, AVSAT et GLONASS).

Cette étude a aussi fait une évaluation superficielle de certains systèmes de navigation non basés sur l'approche radio. Ces systèmes sont souvent couplés avec des systèmes de radionavigation/ localisation (ETAK, VDO, EVA, CARIN, boussole).

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GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACS	Active Control System
ARCS	Automatic Route Control System
ATCS	Advanced Train Control System
AVLC	Automatic Vehicle Location and Control System
CAA	Canadian Automobile Association of Canada
CIS	Communication and Information System
CNES	Centre National d'Etudes Epatiales
CNR	Canadian National Railway
CRT	Cathode Ray Tube
CUTA	Canadian Urban Transit Association
DME	Distance Measuring Equipment
DND	Department of National Defense
DOD	Department of Defense (US)
DR	Dead Reckoning
ELT	Emergency Locator Transmitter
EMR	Energy, Mines and Resources
ETA	Estimated Time of Arrival
FM	Frequency Modulation
GPS	Global Positioning System
HF	High Frequency
INS	Inertial Navigation System
KHz	Kilohertz
KW	Kilowatts
LCD	Liquid Crystal Display
LOP	Line of Positioning
METS	Mobile Emergency Tracking System
MHz	Mega Hertz
MSS	Mobile Satellite Service
MSAT	Mobile Satellite Program
NASA	National Aeronautics and Space Administration
NCC	National Capital Commission
NDB	Non Directional Beacon
NNSS	Navy Navigation Satellite System
NOAA	National Oceanic and Atmospheric Administration
OC TRANSP	Ottawa Carleton Transit Commission
OPP	Ontario Provincial Police
P&D	Pick-up and Delivery
PPS	Precise Positioning Service
PTT	Platform Transmitting Terminal
RDSS	Radio Determination Satellite Service
RF	Radio Frequency
RV	Recreational Vehicle
SARSAT/COSPAS	Search & Rescue Satellite System
TACAN	Tactical Air Navigation
TTC	Toronto Transit Commission
UHF	Ultra High Frequency
UP	Union Pacific
VHF	Very High Frequency
VLf	Very Low Frequency
VOR	Very High Frequency Omnidirectional Range

1.0 INTRODUCTION

1.1 BACKGROUND

Recent technological advances are rapidly making it possible and cost-effective for surface users to benefit from the advantages of enhanced mobile communications and radionavigation equipment. It is expected that over the next decade a number of surface user groups for radionavigation systems will emerge.

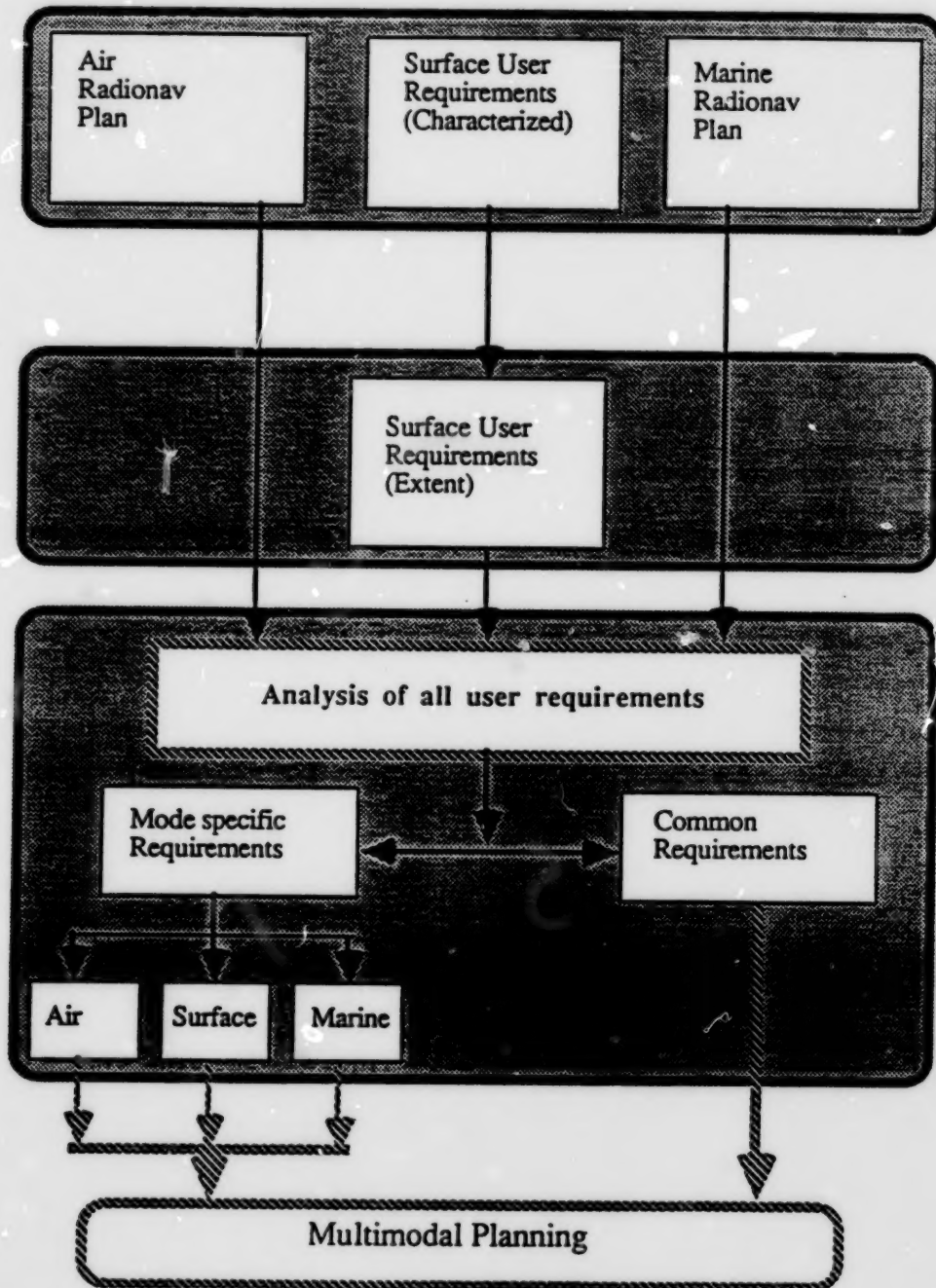
The purpose of this report is twofold. First, to identify and classify prospective user requirements and analyze the various unique and common radionavigation services likely to be required by each of the major user groups and second, to identify the current extent of use by type of radionavigation system for the various groups identified and to develop a forecast of type of system to be adopted and use growth patterns for each group from 1988 to the year 2000.

This report describes the methodology used to conduct surveys of users and suppliers and the probable evolution of the various alternative radionavigation systems. It also typifies user requirements, establishes an estimate of current usage by systems by group, and develops a forecast of the systems likely to be adopted by each group as well as the trend and extent of use by the year 2000. Finally, it identifies surface equipment suppliers and their equipment capabilities, and reviews and documents radionavigation systems available (or planned) for surface use in Canada.

Subsequent activity will determine common user requirements for Air, Marine and Surface such that this information could be used to support future joint radionavigation planning efforts and the integration of this planning into international agreements.

NOTE: Throughout this report the term "radionavigation/location" is abbreviated to "radionavigation".

FIGURE 1 : PROJECT FLOW DIAGRAM



1.2 OBJECTIVES AND SCOPE

The objectives of this report are to:

- o identify the user requirements for all civil and military users related to position/location issues for the land/surface mode;
- o synthesize the user requirements by identifying common and unique requirements for each group;
- o gather details from signal providers and equipment suppliers about actual systems that exist, are planned to exist or might possibly exist for use by Canadians over the medium and long term.
- o Describe the actual and potential surface uses of present and proposed radionavigation systems;
- o Develop scenarios for the probable evolution in terms of technical capability and cost of the three major types of radionavigation systems (active satellite systems, passive satellite systems and ground based systems. These scenarios cover the period 1988 to 2000);
- o Estimate the present extent of use of the various major types of radionavigation systems for each user group; and
- o Forecast the type(s) of system(s) likely to be selected by each group, the timing, the trends and the probable extent of use by the year 2000.

The report covers a wide range of common use radionavigation systems; it deals with Canadian Radionavigation facilities that are likely to be federally or privately operated and includes both civil and military facilities as well as non-Canadian systems which could be made available to Canadian users. The focus is on the uses of radionavigation systems and does not cover, to the same extent, the use of non-radionavigation systems such as on-board odometer based systems, dead reckoning systems or proximity devices. As a result, the rail sector, has been included in the user requirement section of the report, but, has been excluded from the extent of use study section.

The major radionavigation systems covered are:

- o LORAN-C
- o OMEGA
- o TRANSIT
- o Global Positioning System (GPS)
- o Radiodetermination Satellite Services (RDSS)
- o Advanced Train Control System (ATCS)
- o Proximity devices
- o Radio, TV and other communication systems

The report also considers communications navigation aids other than those utilizing radionavigation for completeness.

Some attention is also accorded to non-radionavigation aids since many surface navigation requirements can be addressed using such systems.

The scenarios used throughout this report deal mainly with major national coverage radionavigation facilities which are likely to be government or privately operated and includes both civil and military systems as well as non-Canadian systems which are available to Canadian users. The three radionavigation systems covered by this report are:

- o Active Satellite Systems (GEOSTAR)
- o Passive Satellite Systems (GPS)
- o Ground Based Systems (LORAN-C)

The report also considers the communication aspects of radionavigation systems.

The 15 user groups included in this report include:

- o civil government;
- o military;
- o commercial users;
- o private users; and
- o non-transportation related users.

1.3 APPROACH AND METHODOLOGY

1.3.1 Approach

This study was structured as a directed probe rather than as a survey sample. Respondents were not selected randomly, they were chosen specifically to represent user groups and sub-groups based upon our perception of their ability to typify user needs.

The Radionavigation Systems Scenarios were built by combining published information and information obtained during interviews with specialists. Estimation of present and future use were obtained from interviews with selected representatives of each user group which were selected because of their involvement with radionavigation systems. To the extent possible, information on "Sector Size" and forecasted "Sector Size" were obtained from official Statistics Canada sources. In many cases, Statistics Canada sources were unavailable. Other sources such as industry associations, publications and estimates by specialists have been used. Sources of estimates and forecasts have not been indicated to protect the interests of the companies.

1.3.2 User Requirements Survey Methodology

The methodology consisted of four phases:

Phase 1: Documentation Review/Expert Interviews

A review of all available relevant documentation on user requirements for surface navigation was conducted in order to determine the probable requirements of prospective users. This phase also included a number of contacts and interviews with experts.

Phase 2: Interview Guidelines Development and Selection of Respondents

This phase included the design of interview guidelines, and pretesting of these guidelines through discussions with experts. It also included the selection of respondents.

Phase 3: Interviews

To insure that respondents had the time to respond and had given some thought to the issue at hand, all respondents were contacted in advance. The purpose of the study was explained and they were asked to schedule a specific block of time for the actual interview. A list of interviewees is included in Appendix A. The majority of interviews were conducted by telephone and lasted approximately 1 hour. 52 interviews were conducted.

Phase 4: Data Synthesis

The data obtained from the interviews was first grouped in 15 types each with its own set of summary requirements. From these 15 types, the surface user requirements were categorized by:

- function
- accuracy
- coverage
- update rate

1.3.3 Radionavigation Systems Framework and Scenarios Development Methodology

To establish the demand forecast by group of users over time, the following approach was used:

- o An overall radionavigation use framework was developed; and
- o Radionavigation Systems were then slotted in one of three categories:
 - Active Satellites Systems, represented by the GEOSTAR example;
 - Passive Satellites Systems, represented by the GPS example; and
 - Ground Based Radionavigation Systems, represented by the LORAN-C example.

We recognize a fourth category incorporating non-radionavigation systems such as odometer based systems, dead reckoning and proximity devices based systems. These have been mentioned when used in conjunction with one of the above. Exclusive use of non-radionavigation systems being outside the scope of this study, instances of such use have been noted but not fully researched and user types such as railways which use exclusively non-radionavigation devices have been excluded.

For each category of radionavigation system, a probable evolution scenario, based on the general framework, was developed using the following methodology:

Phase 1: Documentation Review

For each of the radionavigation systems included in the study, a review of the available documentation was performed with a focus on the following factors:

- date of initial system availability;
- basic functions of system;
- planned and expected evolution of functions over time (1988 to 2000); and
- pricing evolution for on-board equipment and fees over time (1988 to 2000).

Phase 2: Development of a Potential Ground Surface Use of Radionavigation Framework

Using information from the Documentation Review (and knowledge accumulated during the previous Part 1 study, a potential ground surface use of radionavigation framework was developed. This framework recognizes six possible levels of use. Each level incorporates a higher information/communication requirement than the previous one, or a higher precision positioning accuracy, or both.

Phase 3: Interviews with Experts

This phase included a number of contacts and interviews with experts in the various radionavigation systems under consideration. The objective was to validate the framework and to identify the present and future capabilities of each system in the context of the proposed framework.

Phase 4: Development of Three Alternative Scenarios

On the basis of the information obtained in the preceding phase, three scenarios were developed.

Phases 2, 3 and 4 were not entirely sequential. A considerable amount of feedback occurred between the framework and the scenario building process. As a matter of fact, each scenario, as well as the basic framework evolved through no less than four versions until they were finally considered fully developed.

1.3.4 Current and Forecasted Extent of Use Methodology

Once the general framework and the alternative scenarios were established, they were used as one element to forecast the timing, type and probable extent of use for each group under study. The methodology used for this purpose was as follows:

Phase 1: The obtaining of information on current use from each group.

Information on current radionavigation systems use was obtained from documentation review and from interviews a number of which were conducted in the context of the acquisition Part I Study.

Phase 2: The obtaining of information on present and forecasted (year 2000) "Sector Size" for each group.

For each potential user group, a description of the typical user was obtained from the Part I study. For example, the typical intercity bus encompasses scheduled and chartered buses while the typical commercial trucking user includes pick-up and delivery vehicles and long haul trucks. In some categories such as Correctional Services and Fishing, Hunting, Search and Rescue, the typical user refers to an individual rather than to an existing number of vehicles. In the case of agricultural use, the typical

user refers to the type and size of tractors as well as to a type of use (wheat farming).

Because of the variety and specificity of radionavigation potential users types, information from government sources such as Statistics Canada was generally lacking. When this occurred, information was sought from other sources such as industry publications or industry experts. In a few cases, no reliable estimates or forecasts have been obtained. In all cases, the sources have been indicated.

Phase 3: Comparison of the group needs and desires with the various system Scenarios capabilities.

The needs and desires (present and future) of each major user group was compared with the capabilities of the various systems as developed in the scenarios. The comparison process made it possible to match each potential user group with one or more systems over the time frame of the forecast.

In some cases, a given user group may be closely matched with one system in the short-term because its needs are still limited but may, later on, have to switch to a different system as its needs become more demanding.

Phase 4: Probable choice of system, timing and extent of use by the year 2000 for each group.

The final step was to project an adoption trend for each group. This was done taking into consideration the following criteria:

- o the importance of each function offered to current and future needs; and
- o the degree of satisfaction gained in terms of accuracy, availability and costs.

As a result of the above process, a probable scenario incorporating best estimates of volume and type of demand was developed for each group of potential users.

1.3.5 Supplier Survey Methodology

The methodology consisted of four phases:

Phase 1: Documentation Review

A review of all available documentation relevant to radionavigation systems for surface use was conducted to assist in determining the criteria for questionnaire format and in identifying the most appropriate sample of suppliers of radio-navigation equipment. Documentation reviewed included: technical reports; journal and magazine articles; conference proceedings and the Business Opportunities Sourcing System (B.O.S.S.).

Phase 2: Questionnaire Development and Sample Selection

The questionnaire was designed to elicit information on the radionavigation equipment a company offers or may be developing for surface users. The questionnaire consisted of three sections:

- o Section I: identification and general description of company products and type of equipment offered;
- o Section II: company's actual/planned use of product, expected base market for surface use, and current and future market information; and
- o Section III: Specific product characteristics, functions and capabilities.

Following the development of a draft questionnaire, it was pre-tested to illuminate its ability to solicit the most accurate and relevant information.

Finally, based on the documentation review, an initial sample of 41 suppliers of radionavigation equipment was selected for questionnaire distribution.

Phase 3: Data Collection and Follow-Up

Questionnaires were sent to the appropriate company representative. Participants were given eight days to respond and a reminder was issued as the deadline for completion approached. Due to the low response rate, approximately 30 calls were made to increase compliance and additional copies of questionnaires were sent to replace those which were misdirected or lost. Also, when possible, questionnaires were completed with the company representative over the phone. A total of 18 out of 41 suppliers responded. Five companies did not make radionavigation equipment and two companies did not expect that their products would be used for surface use.

Phase 4: Data Synthesis

The information collected was integrated with other data obtained from technical documents supplied by system proponents and is summarized in Appendix B.

1.3.6 Radionavigation and Other Relevant System Descriptions

This section was developed through an extensive literature review which included material provided by respondents to the user survey as well as technical reports; journals and magazine articles; and conference proceedings.

In addition to the documentation review, a number of interviews were conducted with experts in the various systems. Whenever possible contacts were made with the "provider of the signal" to obtain up-to-date information on the system's possible utilization for surface navigation.

1.4 LIMITATIONS OF THE METHODOLOGY

The methodology utilized was considered the most likely to yield trustworthy results. It, nonetheless, has a number of limitations which have been listed below:

- o The evolution of the technology in the field of radionavigation is very rapid and known systems may be obsolete far sooner than expected.
- o Cost projections are very subjective. The cost of a satellite based radionavigation service is tied to at least two areas which are undergoing considerable growth and dramatic per unit cost reductions, namely: the cost per CPU (Central Processing

Unit) has been falling by as much as 90 per cent with each successive computer generation (every seven years or so) and the cost of putting satellites in orbit has evolved along the same pattern. Furthermore, system costs are mainly fixed and a growth in demand would rapidly be translated in a considerable per unit cost saving.

- o The number of potential users can, at best, be estimated. Available statistics both official and those maintained by the industry, are of a global nature and fail to discriminate along the lines required for precise forecasts.

2.0 FRAMEWORK AND SCENARIOS

2.1 INTRODUCTION

Radionavigation systems have the ability to satisfy various levels of user requirements. These are shown in Figure 2 and range in ascending degrees of accuracy from simple off-line monitoring to fully automated remote guidance capability for non-tracked vehicles. These 'uses' are described in greater detail in sub-section 3.2 below.

In order to allow for a meaningful comparison between systems, we have developed a radionavigation systems capabilities framework as well as three specific system scenarios, namely:

- o Active Satellite Systems;
- o Passive Satellite Systems; and
- o Ground Based Radionavigation Systems.

2.2 THE POTENTIAL SURFACE USES OF RADIONAVIGATION SYSTEMS - A COMPARISON FRAMEWORK

2.2.1 Level 1 - Off-Line Monitoring

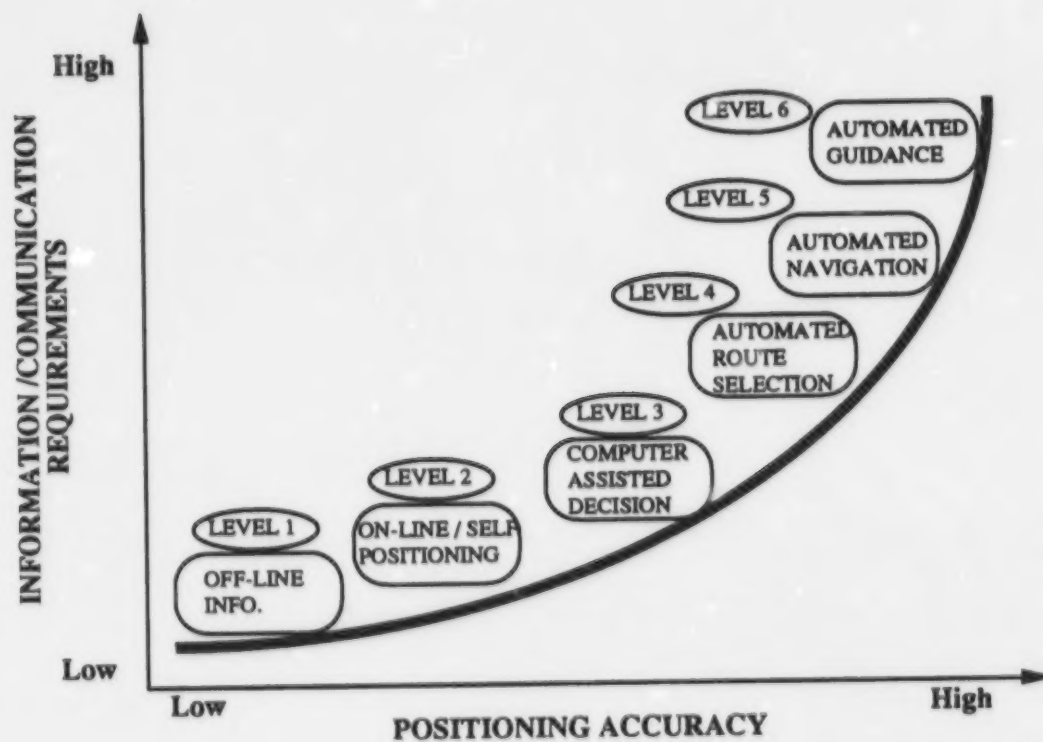
Off-line monitoring permits the continuous off-line monitoring of vehicle, operator and cargo related functions for planning, maintenance, accounting and control purposes. Positioning accuracy requirements are low, the required information can generally be supplied from an odometer reading or be input by the operator (e.g., border crossings for road and fuel taxes calculations purposes). Information requirements can be entirely satisfied by vehicle generated data (speed, temperature, etc.). No on-line communication is required. All systems under study have the capability to supply the necessary positioning information.

2.2.2 Level 2 - Positioning

Positioning can be either self positioning or third party on-line location monitoring. Self positioning is primarily geared to the needs of the vehicle operator while third party on-line location is primarily aimed at fleet managers. Both self positioning and third party on-line location require roughly the same level of accuracy. Self positioning requires a higher update rate but has no information/communication requirements. Third party on-line positioning has a lower update rate requirement but it involves a medium (limited data) information/communication requirement.

GEOSTAR (in conjunction with Fleet Track) currently allows third party on-line location monitoring. This type of information is sufficient to permit on-line dispatching decisions. Positioning accuracies required are generally in the 100 metres plus range in urban areas and from 1 to 5 Km on major highways and in

**FIGURE 2: POTENTIAL SURFACE USES OF
RADIONAVIGATION / COMMUNICATIONS
SYSTEMS**



rural areas. The only information required is vehicle position, real time communication requirements are limited (short data messaging at fixed intervals of 30 minutes or more), but dispatching tradition favours flexible voice communication capabilities.

Used independently, LORAN-C satisfies the requirements of Level 2 with respect to self positioning in rural areas. Used in conjunction with a communication system it also satisfies the requirements of the Level 2 third party on-line location monitoring function.

When GPS becomes fully available, (1992) it will fulfill the self positioning requirements of Level 2, but the lack of communication interface will restrict its use for dispatching and fleet management purposes. GPS plus integrated communication systems (of various kinds) should, however, be available by 1995.

Self positioning can also be obtained from a variety of odometer and proximity device based systems.

2.2.3 Level 3 - Computer Assisted Decision

Proximity devices already allow urban transit vehicles to make certain "Computer assisted decisions" such as "Slow down", "Stop" or "Accelerate" to maintain the posted schedule. Positioning accuracy is generally in the 15 to 65 metre range.

Information requirements are dependent on optimization objectives. If the vehicle is to adhere to a preset schedule, the only information required is that pertaining to the schedule and the vehicle location. This option involves little communication requirements (if schedule adherence must be reported, there is a need for intermittent data communication). If optimization involves various vehicles (e.g., various trains on a single track or a fleet of urban buses on a given heading), information updating and communication requirements may increase substantially (still in data format).

Passive Systems and LORAN-C (when coupled with a Dead Reckoning device) can supply the on-board information required for single vehicle level computer assisted decisions. Their use in connection with multiple vehicle scheduling is limited by the characteristics of the fleet (urban transit/highway trucks) and of the communication system to which they are to be coupled with. For instance, if all the vehicles are operating in an area which can be covered by a private RF network, polling cycles and transmission delays may be short enough to manage bus fleets. Requirements for managing highway truck fleets can be met by a number of systems (MSAT, Cellular, etc.).

Active systems could be used for single vehicle schedule adherence when in "high ratio" update mode, but even when coupled with Dead Reckoning devices, they do not have the information update rate required for Level 3 computer assisted decisions involving urban fleets or multiple vehicles operating in close proximity.

2.2.4 Level 4 - Automated Route Selection

Automated route selection allows for the automated selection of an optimum route between points on the basis of pre-determined criteria and may involve on-line environmental inputs gathered by the system. Positioning accuracy remains in the 15 to 65 metres range, while real-time environmental input gathering and communication (road, traffic conditions) requirements are high. When coupled with an on-board computer and digital map, such systems are capable of generating an optimum route based on pre-set criteria such as shortest route or most scenic route, etc. In order to optimize a route according to environmental data such as traffic volumes and accidents, all systems require

external inputs. Given a sufficient number of subscribers, Active Satellite Systems could use a polling process to generate the data required for route optimization. Failing that, all systems will depend on inputs generated by road bed or proximity device sensors. In its first phase, the European Prometheus Project should supply this type and level and information from sensors imbedded in the roadway.

2.2.5 Level 5 - Automated Navigation

With automated navigation, although the vehicle operator retains the actual driving responsibility, all the navigation decisions are made by the system which issues timely sequential instructions. To avoid diverting the driver's attention from the road, navigation instructions may be relayed verbally or through a "head-up display" device. The accuracy requirement is in the one to five metres range. Such systems may be at a disadvantage when required to supply position information updates compatible with high driving speeds.

Performance of Level 5 functions may or may not be associated with a Level 4 capability. In other words, automated navigation may not necessarily be associated with route optimization.

2.2.6 Level 6 - Automated Vehicle Guidance

At the highest level a radionavigation/communication system is capable of fully automated vehicle guidance in urban and open road settings. To be able to satisfy such a function, requires a very high absolute and relative accuracy (at the centimetre level). It must have a high update rate, be impervious to interferences and be able to obtain and process a large amount of environmental data (road and traffic) in real time. Among the presently available or planned systems, only proximity devices appear to have the required characteristics for automated guidance and only in the limited area of tracked vehicles.

2.3 SCENARIO 1: ACTIVE SATELLITES SYSTEMS

2.3.1 Introduction

GEOSTAR is the primary example of an Active Satellite System. GEOSTAR is structured to answer "Where are you?" and the "Where am I?" types of questions. The hub (GEOSTAR base station) interrogates the "remote" (on-board equipment) through one satellite. The "remote" sends a message which is picked up by three geostationary satellites, each of which then retransmits it to the hub where it is time stamped and analyzed to determine the location of the vehicle (by triangulation, using the time differential between transmission and reception through each individual satellite). The information is then forwarded to the subscriber's headquarters over conventional phone lines. If the vehicle operator wants to know his position, he can use the keypad attached to the remote and send a "position request" message. Upon receipt of such a request, the hub will rebroadcast the next calculated vehicle position to the remote using the 97 characters data transmission capability built into the system.

GEOSTAR is a privately owned fee-for-service system. Currently, GEOSTAR is offering a RDSS type service (Radiodetermination Satellite Service). Eventually, GEOSTAR is expected to offer a DLMSS service (Digital Land Mobile Satellite Service). Initially, subscribers are expected to sign on for one or two position updates per hour (known as a "position transaction"). Because the system must interrogate the on-board equipment, there is a limit (and a delay) associated with how often a subscriber can be "polled" (at a realistic price).

With less than three (well positioned) satellites in place, the system requires a digitized map giving vertical elevation in order to be able to determine a position with reasonable accuracy. GEOSTAR is being equipped with such a map, but its accuracy is in the 50 metres range which further inhibits the (initial) accuracy of the system.

The present cost for the GEOSTAR service is \$45.00 per month for one position transaction per hour (see Figure 3). Each additional transaction costs only five cents. The cost per remote unit is \$3,500 installed (see Figure 3).

2.3.2 Advantages of Active Systems

Active Systems have the following advantages:

- o GEOSTAR is already available but it is currently using LORAN-C for positioning (1/4 mile) accuracy. Despite past launch failures, GEOSTAR expects to be fully operational with three satellites aloft in 1992;
- o On-board receivers/transmitters need not be complex;
- o This is a user-pay service;
- o Accuracy will be in the 50 metres range; and
- o The current 97 characters one-way communication capability will be increased to 105 characters, two-way in 1992. At that time, GEOSTAR is also expected to launch its Digital Land Mobile Satellite Service which will include voice messaging (two-way), remote to remote communication and will be ISDN compatible.

2.3.3 Disadvantages of Active Systems

GEOSTAR has the following disadvantages:

- o The number of possible subscribers is finite (when operational, the GEOSTAR system will be able to accommodate 10 million plus position transactions per hour);
- o The scheduled update time is fixed. The 30 or 60 minutes update rate limits the use of the system for certain applications;
- o Current messaging capabilities are limited (one-way, data only). Two-way communication is being announced;
- o GEOSTAR "System 2" is unusable in the North and Arctic (there is a separate polar orbital "System 1" which has an update rate of 270 minutes and is based on one satellite only);
- o Lack of redundancy;
- o Multipath and shadow problems in industrial and urban areas ("urban canyon effect"). Because the few satellites available are all geosynchronous, shadows may be particularly severe in Canada and will require coupling with a Dead Reckoning system; and
- o GEOSTAR is a private company (continuity of service not guaranteed by government).

2.3.4 The Active Satellites System Scenario

The above characteristics and information obtained from GEOSTAR and a variety of industry sources have led to the following forecast Scenario.

By 1989, GEOSTAR will be able to minimize shadows and multipath problems in built up and industrial areas by adding some form of Dead Reckoning System for use between updates and in shadow and multipath areas. This will make it usable in major Canadian urban areas and make it operational for use in Level 2 functions (dispatching) in all of Canada south of 55 degrees Latitude (see Figure 4). There is, however, a risk that the long update cycle may result in considerable degradation of accuracy in urban areas.

By 1992, GEOSTAR will increase messaging capability to two ways, voice and data. The additional communication function will increase both the equipment and operating costs, but it will make the system more attractive for dispatching purposes (Level 2).

By the mid/late 1990s, or possibly earlier, GEOSTAR will either have successfully coupled its remotes with a secondary update system such as GPS or LORAN-C to increase positioning accuracy between scheduled updates, and/or it will be offering an optional low cost switchable "high update" ratio service compatible with the needs of Level 3 and 4 functions in urban and industrial areas (see Figure 4). Because of the relatively low update rate, the utility of GEOSTAR for level three functions (computer assisted decisions) will probably be limited to independent users and to highway truck fleets. Urban transit systems, and other similar systems, require a much more frequent polling and communication rate than what is being offered.

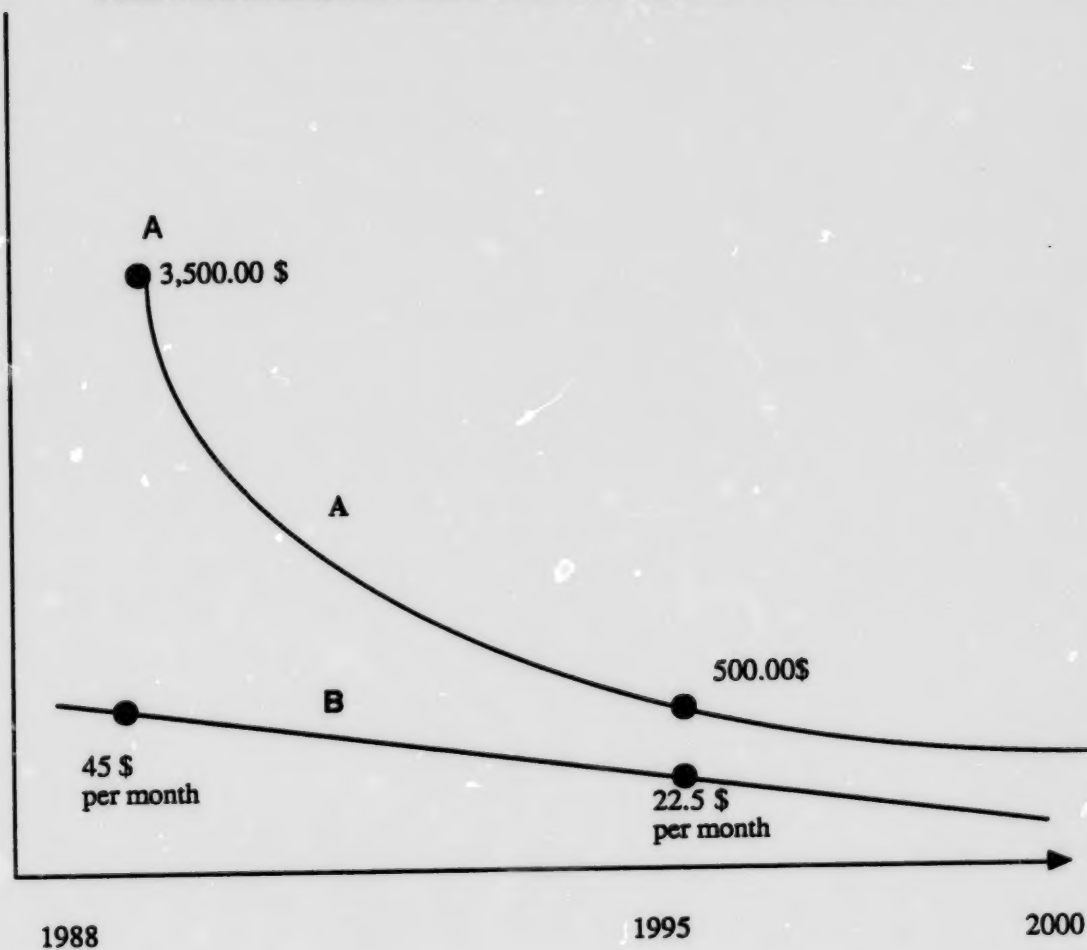
By 1995, the cost of the remote unit is expected (by GEOSTAR) to drop to the \$500 range

while toll costs are expected to drop 50 per cent in real terms (see Figure 3). At this point in time, GEOSTAR will have a considerable cost and service advantage over passive systems such as GPS. It will be able to satisfy Level 2 (on-line/self positioning and tracking) as well as non-urban Level 3 functions (computer assisted decisions) (see Figure 4). If GEOSTAR itself is interfaced with an external system capable of gathering and analyzing local route and traffic conditions, it would be in a position to fulfill Level 4 requirements (when using the "high update" service) (see Figure 4).

Active Systems will take an early lead (1988/1992) mainly because GEOSTAR is already available, moderately priced and because (in conjunction with such map matching software as Fleet Track) the functions it offers are especially useful for fleet management. Large fleets are expected to be the innovators in this area.

Because of their nature, Active Systems have a relatively slow update rate. Due to the number of subscribers, the polling cycle is, at best, in the order of minutes, not tenths of seconds. As a result, current Active Systems are not designed for use in Levels 5 and 6 (automated navigation and automated guidance) (see Figure 4). This deficiency may be partially corrected through the use of add-on devices but the current assessment is that Active Systems will be superseded by hybrid Active/Passive Systems by the late 1990s or early 2000s.

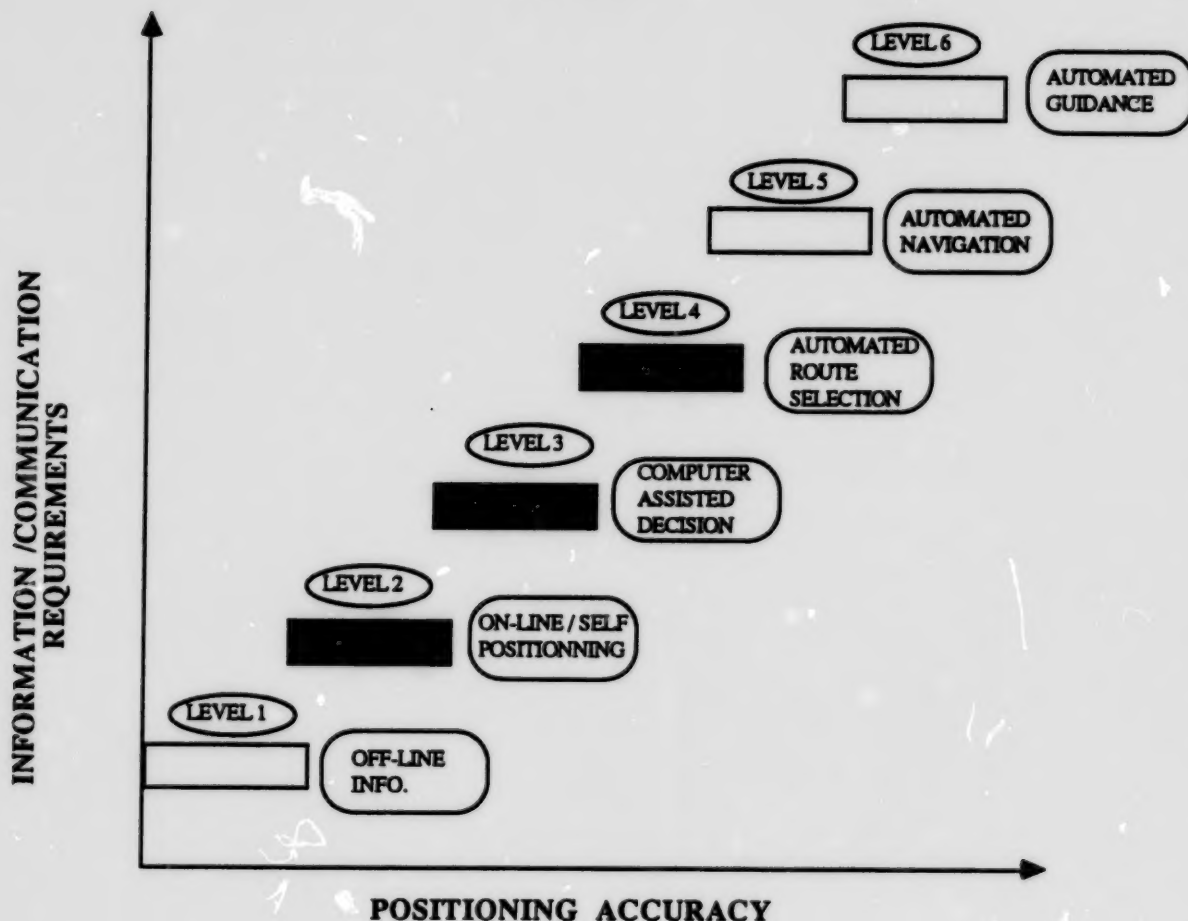
**FIGURE 3:
THE PROBABLE EVOLUTION OF GEOSTAR "REMOTES"**



A cost of on-board receiver

B : toll cost per month per vehicle

**FIGURE 4:
POTENTIAL FUNCTIONS
OF ACTIVE (GEOSTAR)
RADIONAVIGATION/COMMUNICATIONS
SYSTEMS**



- | | | |
|---|---|--|
| A |  | NOT COVERED BY SYSTEM |
| B |  | POSSIBLE IF SYSTEM IS COUPLED WITH
DEAD-RECKONING DEVICE AND DIGITIZED MAP MATCHING |
| C |  | LIMITED CAPABILITIES (SINGLE VEHICLES AND
HIGHWAY FLEETS) |

2.4 SCENARIO 2: PASSIVE SATELLITES SYSTEMS

2.4.1 Introduction

GPS (Global Positioning System) is the primary example of a Passive Satellite system although it is possible that the USSR and the EEC may develop competing alternatives. Passive Systems are structured to answer the "Where am I?" question, not the "Where are you?" one. In the proposed GPS system, 24 satellites will be put in various orbits around the earth by the U.S. Department of Defense (Air Force). Between six and 10 satellites will be visible at any time in North America. In a Passive System, the on-board receiver uses signals originating from a number of satellites (each satellite's signal indicates the precise orbit and time of transmission) to determine the vehicle position. When the GPS network is fully deployed, civilian users will be able to achieve position accuracies in the 100 metre range (using the commercial acquisition (C/A) code mode). If U.S. national security fears are relaxed, the system may be allowed to operate at its inherent accuracy range of 40 metres. With the addition of a number of local (500 km range) differential stations, accuracy would be raised to the one to five metres range. Because GPS is a Passive System, GPS satellites have no messaging capabilities. GPS receivers can, however, be coupled with radio communication systems to emulate Active Satellite Systems.

2.4.2 Advantages of Passive Systems

Passive Systems have the following advantages:

- o No user fees contemplated at present;
- o Available world wide, including North and Arctic;
- o Initial civilian accuracy in the 100 metres range, possible 40 metres;
- o "Differential" accuracy in the one to five metres range;
- o Update rate can be very rapid;
- o Number of simultaneous users is unlimited;
- o The GPS System is supported by the U.S. Government;
- o Reliability (many satellites); and
- o High level redundancy will minimize multipath and shadow effects except in downtown areas surrounded by high buildings.

2.4.3 Disadvantages of Passive Systems

Passive Systems have the following disadvantages:

- o Not expected to be fully operational before 1992;
- o No independent messaging capability;
- o No direct "Where are you?" capability;

- o On-board receiver very complex (but user interface will be simple);
- o Some shadow in urban settings;
- o Accuracy is insufficient for Level 5 without differential signal coverage;
- o Accuracy is insufficient for Level 6; and
- o U.S. Government retains the right (and capability) to impose user fees.

2.4.4 The Passive Satellite System Scenario

The above characteristics and information obtained from a variety of industry sources have led to the following forecast Scenario.

By 1992, GPS will be interfaced with digitized maps. Given a map matching capability, the system will be usable for Level 2 (self position only, no third party locating) and Level 3 functions (computer assisted decisions) in non-urban areas (see Figure 6). The map matching interface may allow for some Level 4 capability (automated route selection), but it will be in the form of a "non-optimized" computer assisted route selection because the system will lack on-line information on road and traffic conditions.

By 1993, Passive Satellite Receiver based systems will be able to minimize shadows and multipath problems in built-up and industrial areas by adding some form of Dead Reckoning System. This will make Passive Systems fully usable in major Canadian urban areas and will give them full Level 3 capability (see Figure 6) with regard to individual vehicles. Computer assisted fleet level decisions will still require an add-on communication system.

By 1993, it will be possible to couple most GPS receivers with an MSAT, VHF or cellular based communication systems to allow for "Where are you?" capability. Passive Systems will then become usable for fleet/vehicle tracking and dispatching (Level 2) (see Figure 6). Given the various upgrades mentioned above, this capability will extend to urban as well as rural, remote and northern areas. Level 4 (automated, optimized, route selection) will become possible (see Figure 6) provided the receiver is linked to an external system capable of gathering and retransmitting the on-line road and traffic conditions required for that function. It is not expected that such systems will become widely available in Canada before the year 2000.

Although complex, GPS receivers will benefit from a more pronounced experience curve (U.S. military use and world wide applicability) and are, therefore, expected to become cost competitive with Active Systems receivers by late 1990's. On-board receiver costs for surface land use (as opposed to air and marine units) are expected to be in the \$800 to \$1,000 range by 1995 (see Figure 5). By the year 2000, the cost of an integrated receiver (differential capability, Dead Reckoning, voice and data communication capability) is expected to be in the \$200 to \$400 range (see Figure 5). The preceding price forecasts are rough estimates based on specialist opinions which are themselves based on cost reductions observed for other high volume electronics items.

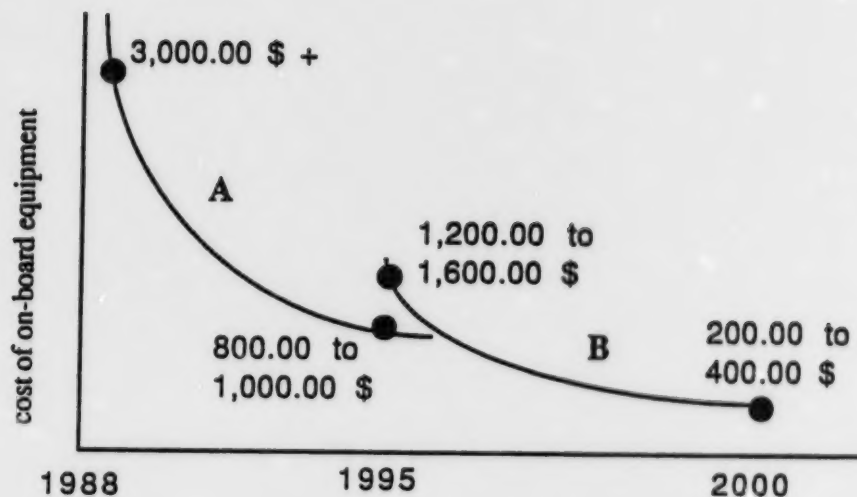
By 1995, it may be possible to use the GPS C/A code in a differential mode in several Canadian regions (if the Canadian Government implements the proposed construction of a string of GPS/ACS differential stations). This will make it possible to achieve accuracy rates in the one to five metre range (especially if the U.S. Government relaxes the rules on signal degradation now imposed on the GPS). At these ranges it becomes possible to use a Passive System for Level 5 (automated navigation) (see Figure 6).

Because Passive Systems are not subject to fee for use (at least for the foreseeable future), and because they are mainly aimed at the "Where am I?" question, they will initially (1992 - 1995) be most attractive to private and independent users. Once coupled with the appropriate communication system, Passive Systems will be able to answer the "Where are you?" question and will start competing in the fleet management market segment.

Provided the system is interfaced with the appropriate communication systems, use of GPS receivers is expected to grow rapidly after 1995 with the growth being sustained beyond the year 2000. Failure to install differential stations will slow down the Canadian rate of expansion because the system will be limited to Level 4 functions (again, provided traffic and road condition information is available).

Individual users' demand for GPS receivers is expected to grow significantly when Canadian urban areas and major highway stretches are eventually equipped with road and traffic data networks. There are no plans for this to occur before the end of the century.

**FIGURE 5:
THE EVOLUTION OF GPS RECEIVER COSTS**

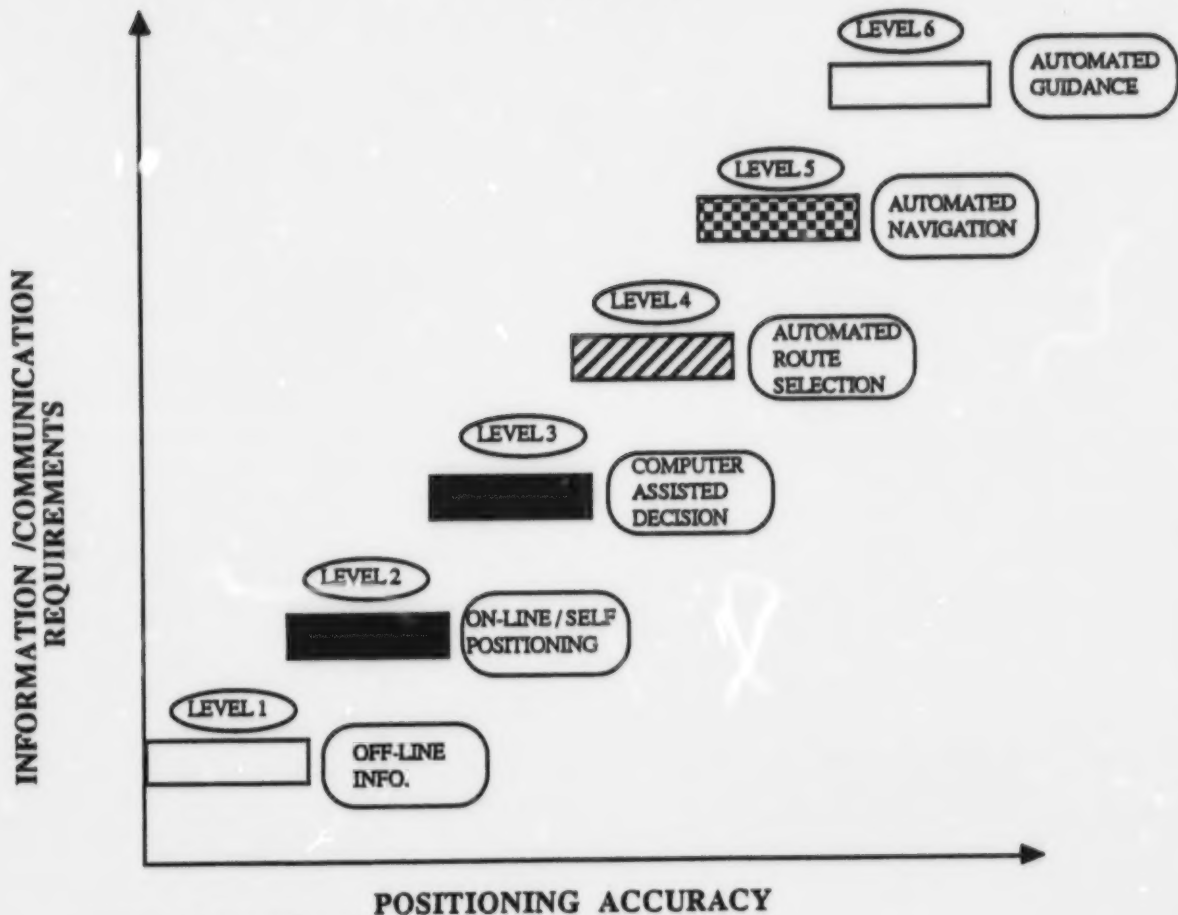


A :On-board receiver only

B :On-board receiver plus differential capability and voice & data two ways communication

* The above are estimates derived from industry sources

**FIGURE 6:
POTENTIAL FUNCTIONS
OF PASSIVE (G P S)
RADIONAVIGATION/COMMUNICATIONS
SYSTEMS**



SYSTEM CAPABILITIES

- | | | |
|---|---|--|
| A |  | NOT COVERED BY SYSTEM |
| B |  | POSSIBLE IF SYSTEM IS COUPLED WITH DEAD-RECKONING AND DIGITIZED MAP MATCHING |
| C |  | POSSIBLE IF SYSTEM IS COUPLED WITH DEAD-RECKONING DIGITIZED MAP MATCHING AND COMMUNICATION DEVICES |
| D |  | REQUIRES TYPE " B " PLUS COUPLING WITH AN ON-LINE EXTERNAL ENVIRONMENTAL INFORMATION SOURCE |
| E |  | POSSIBLE WITH TYPE " C " OR " D " PLUS " DIFFERENTIAL " STATIONS |

2.5 SCENARIO 3: GROUND BASED SYSTEMS (LORAN-C)

2.5.1 Introduction

Of the variety of ground based systems available in North America, LORAN-C is one of the most popular. At present it is widely used for coastal navigation. LORAN-C is essentially geared toward answering the "Where am I?" question. Unless it is coupled with some communication device, a LORAN-C receiver has no autonomous communication capability. Because the LORAN-C signal is not affected by built up areas, it is not subject to shadows and multipath limitations. On the other hand, changes in ground conductivity affect signal propagation causing distortions. As a rule, distortion patterns tend to be constant over rather wide areas and time (most of the variation is seasonal). Maps allowing distortion correction factors (including seasonal and local conditions) are already available for the St. Lawrence River and other shore areas. It is conceivable that most of the information pertaining to Canada could be collected and stored on a single "chip" imbedded in all LORAN-C receivers.

LORAN-C distortions are not random. Relative accuracy is generally better than absolute accuracy. As a result, if the system is calibrated (through a proximity device or a differential station), greater precision can be achieved. With the addition of the appropriate corrections, system accuracy can be brought down to the 15 metre range in most areas.

One of the major drawbacks of the LORAN-C system, with respect to the surface use, is that the Canadian coverage is currently incomplete. LORAN-C coverage is non-existent in the Prairie Provinces and spotty in other areas, although the high density population areas of Ontario and Quebec enjoy adequate coverage. By the Year 1990, the U.S. mid-continent gap should be closed by the North Central U.S. Chain (NOCUS) and most of the Prairie Provinces will have signal coverage.

2.5.2 Advantages of the LORAN-C

LORAN-C in Canada has the following advantages:

- o It is already available in many coastal and Great Lake areas;
- o Accuracy of 1/4 mile is sufficient for many non-urban purposes;
- o There are no fees for use;
- o Is not affected by multipath or shadow areas (urban canyon effect);
- o LORAN-C is a Passive System, position update can be continuous;
- o Low cost receivers (\$250 to \$400 range) are already available (see Figure 7);
- o System is well known, has been in operation for many years;
- o System is government owned and operated (available in Canada and the U.S.); and
- o System is expected to remain available for the next 15 to 25 years.

2.5.3 Disadvantages of the LORAN-C

The Canadian LORAN-C network has the following disadvantages:

- o The system is geared to answering the "Where am I?" question only;
- o Coverage is incomplete;
- o There are no redundancies in the system but distortions are fairly stable;
- o System requires external "fix" points for (higher accuracy) calibration;
- o No independent communication capability;
- o There are no differential stations available or planned for Canada; and
- o Accuracy is insufficient for high level (5 and 6) functions.

2.5.4 The LORAN-C Scenario

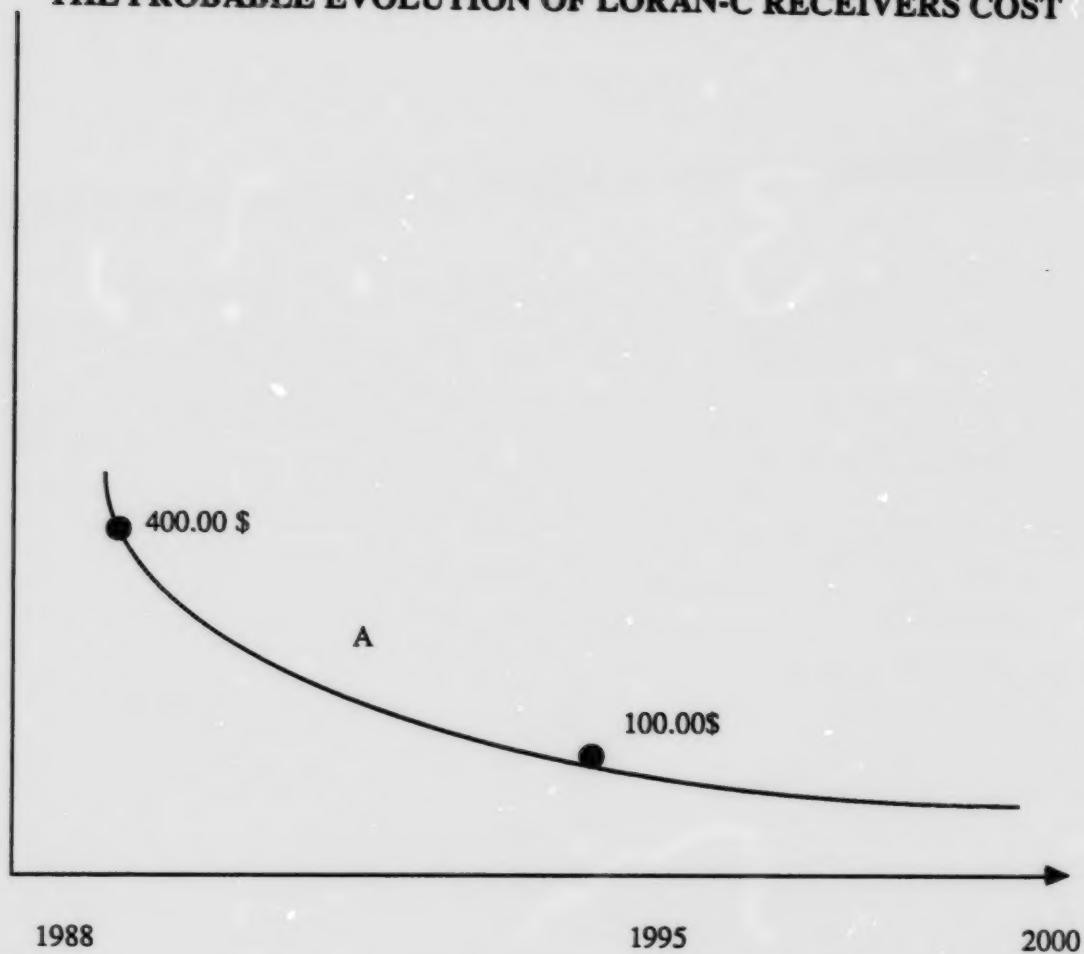
The above characteristics have led to the development of the following forecast Scenario.

LORAN-C receivers for land navigation are already available in the \$250 to \$400 range. It is generally forecasted that by 1992/5 simple receivers will be available in the \$100 range (see Figure 7). As a result, LORAN-C can be said to be already available for the self positioning aspect of Level 2 functions (see Figure 8). Greater diffusion will be helped by the fact that the output is now available in the more desirable digital map matching format rather than in the less user friendly latitude and longitude.

LORAN-C, plus limited data communication capability, is already being offered by GEOSTAR but only as an interim solution until their satellites are available. It is expected that demand will be sufficient to prompt other communications suppliers (especially cellular) to offer this service on a permanent basis (by 1992). Such a service would have a (relatively) low accuracy compensated by a low cost local data and voice communication capability. (If all communications are within a single area, a private FM station would suffice).

This should make such a service desirable for the (Level 2) management of local pick-up and deliveries fleets and even for emergency vehicles, provided the system achieves the level of accuracy required. LORAN-C may become a prime contender for local area dispatching until at least the late 1990s.

**FIGURE 7:
THE PROBABLE EVOLUTION OF LORAN-C RECEIVERS COST**



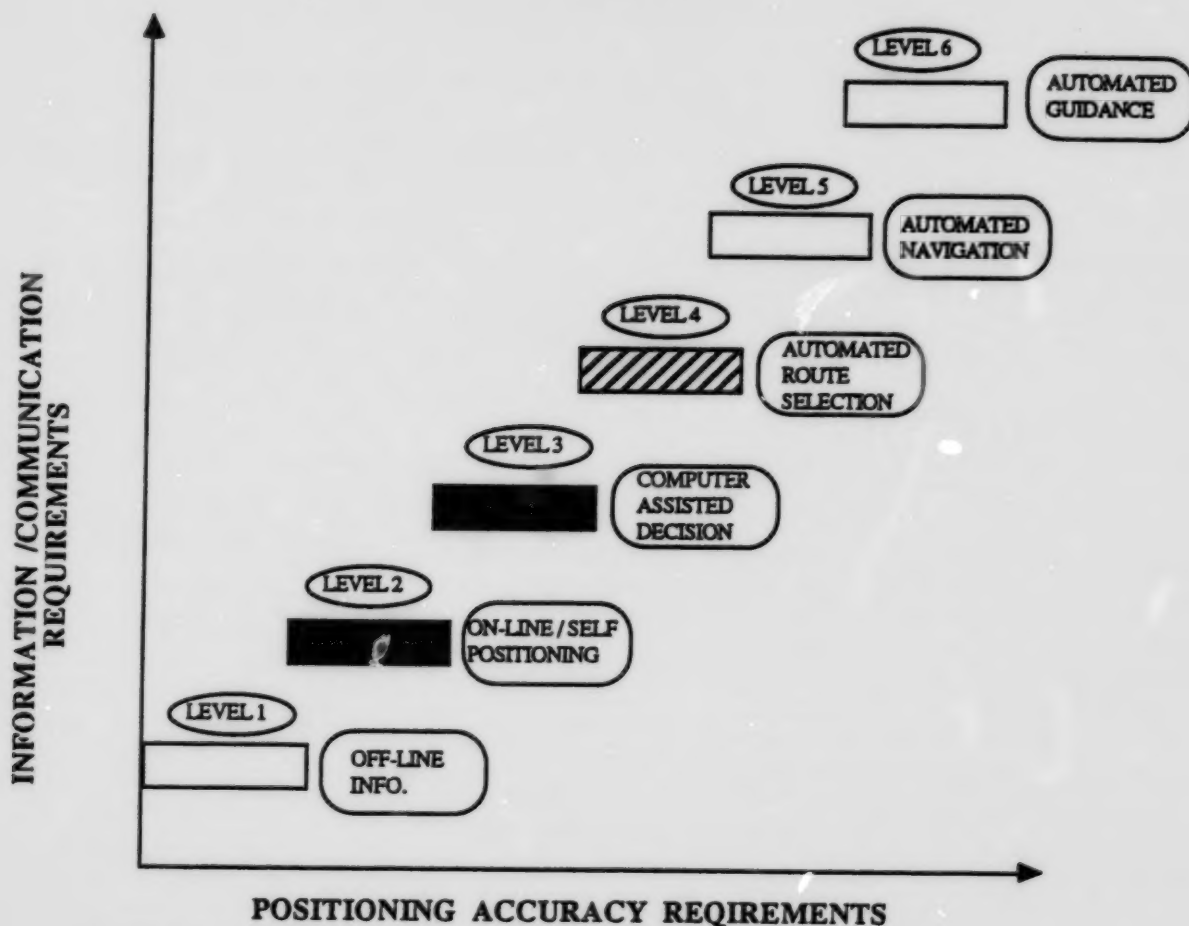
A cost of simple (non communication integrated) LORAN-C receivers

By 1992, LORAN-C receivers coupled with digitized map matching devices will become widely available. They will include a manual or automated "fix" (systems with proximity device capabilities are already available for urban transit use) capability aimed at increasing absolute accuracy on a region-by-region basis. At that point, it is expected that the addition of a map matching capability will no longer increase receiver prices significantly. With the addition of a user friendly interface, the system will become usable for single vehicle Level 3 functions (computer aided decision) (see Figure 8). With the addition of the appropriate communication system it will be usable for fleet management.

Some means to control for signal distortion, probably through an incorporated "chip" will be available before 1995. This will greatly simplify the use of the receivers and make them attractive for Level 3 and even Level 4 (but for non-optimized routing only) to a broad market segment of non-technically oriented private users (see Figure 8).

LORAN-C will have a very high rate of acceptance by the private sector (independent users) and possibly by local pick-up and delivery fleets (including emergency and government service vehicles) from 1990/2 until at least late in the century when satellite based Passive Systems will become more attractive in terms of features (higher accuracy) and cost competitive. Even then, LORAN-C receivers are expected to remain the "no frills, low cost" system favoured by private users (as well as RVs and personal portables) for "retrofits".

**FIGURE 8:
POTENTIAL FUNCTIONS
OF THE LORAN-C
RADIONAVIGATION
SYSTEM**



SYSTEM CAPABILITIES

- A  NOT COVERED BY SYSTEM
- B  POSSIBLE IF SYSTEM IS EQUIPPED WITH MAP MATCHING PLUS COMMUNICATION DEVICE (FOR ON-LINE)
- C  POSSIBLE IF SYSTEM IS EQUIPPED WITH DISTORTION CORRECTION AND DIGITIZED MAP MATCHING DEVICES (ALSO COMMUNICATION FOR FLEET RELATED USE)
- D  REQUIRES TYPE " C " PLUS COUPLING WITH AN ON-LINE EXTERNAL ENVIRONMENTAL INFORMATION SOURCE. MAY REQUIRE " DIFFERENTIAL " STATIONS.

3.0 DESCRIPTION OF SURFACE USER REQUIREMENTS FOR RADIONAVIGATION

3.1 INTRODUCTION

This section describes surface user requirements of positioning/navigation and of estimates pertaining to:

- o Present use of radionavigation systems for each user group under study (if any);
- o "Size of sector" for each group;
- o Forecasted "size of sector" up to the year 2000 for each group;
- o Type of radionavigation system(s) likely to be adopted;
- o Timing and adoption curve; and
- o Forecasted number of users by the year 2000 for each group.

The approach followed was a two step approach. In step one we identified a set of user groups and portrayed the requirement for each group separately. In step two we obtained the necessary information and developed the demand and adoption curve estimates.

Surface users are grouped under five headings:

- Public service;
- Goods movement;
- Military;
- Private use; and
- Other types of use.

Each of the above is broken down further as follows:

PUBLIC SERVICES

- o Urban transit vehicles
- o Taxis and limosines
- o Intercity buses
 - (a) regular route
 - (b) tour/charter
- o Railway
- o Utilities
- o Public Safety and Emergency vehicles
 - policy & security
 - ambulance
 - fire
 - tow trucks
- o Other public service

MILITARY

- o All vehicles
- o Portable/personal

PRIVATE

- o Passenger vehicles
- o Recreational Vehicles (self powered)

OTHERS

- o Surveying
- o Resource Management
- o Agriculture
- o Off Road

GOODS MOVEMENT

- o Courier vehicles
- o Pick-up & Delivery trucks
- o Intercity trucks & tractors
- o Other trucks & vehicles
- o Rail

3.2 REQUIREMENTS INFORMATION

Information on radionavigation requirements for each group is classified as follows:

FUNCTIONS REQUIRED

- o Positioning/location
- o Tracking
- o Monitoring
- o Route guidance
- o Navigation
- o Dispatching

RELIABILITY

95% or less
96-99%
99% +

AVAILABILITY

day
night
continuous

COVERAGE

- o Urban
- o Intercity
- o Regional
- o Rural
- o Remote
- o National
- o Continental

UPDATE RATE (in minutes)

less than 1
1-15
16-30
31-45
46-60
60 +

ACCURACY (in metres)

0-5
6-15
16-65
66-200
200 +

In addition, various ancillary data are presented regarding present practices; benefits expected from new systems; when new systems were expected to be adopted and willingness to pay for new systems.

Definitions

For purposes of describing user requirements, the following definitions are used:

Location/Positioning: Allows the dispatcher (or the user) to locate a vehicle at fixed time intervals such as 30 minutes, 1 hour or more.

Tracking: Allows the dispatcher (or the user) to locate a vehicle at much closer time intervals, from seconds to minutes.

- Monitoring:** Allows the dispatcher (or the user) to obtain information on specific vehicle functions such as temperature, fuel consumption cargo condition, driver performance, etc.
- Route Guidance:** Route guidance allows the driver to select (or instructs the driver to follow) the best route among a given set of points by factoring information on traffic and other route conditions and comparing alternative routes.
- Navigation:** Enables a vehicle driver to determine its position at a given point in time and gives him the directions and direction to be followed to arrive at a given destination.
- Dispatching:** Enables a central facility to control the movement of vehicles.

3.3 THE EXPLANATORY FIGURES

For each group, three figures have been established:

- o Figure type A;
- o Figure type B; and
- o Figure type C.

Details and explanations are included in the example shown on the following pages.

TYPE A

For a given user group, the Type A figure matrix contains the following information:

FIGURE TYPE A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

Relevant
subsector

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
Information provided by relevant interviewees Interviewees not identified											

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Types B and C for the same group of users, Figures B and C contain the following information.

Explanation of figures type B and C

FIGURE TYPE B

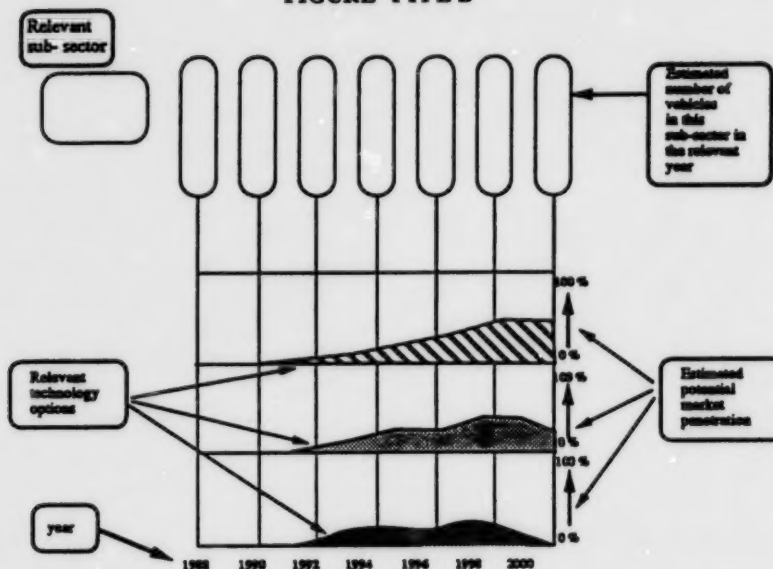


FIGURE TYPE C

Corresponds to user/capabilities levels as per Figure 2	LEVELS	NEEDS	MATCH	Indicates the requirements and needs of this group in terms of the levels in Figure 2.
	6			
	5			
	4			
	3			
	2			
	1			
	Indicates which system - Active = 1 - Passive = 2 - LORAN-C = 3 Best fulfills the expressed needs.			

Figure Type C expresses the radionavigation needs for each sub-sector in terms of one or more of the levels of Radionavigation/communication developed in Section 2, Figure 2. It also indicates which system is best likely to satisfy each particular level of need for that specific sub-sector given its requirements of function, coverage, update, availability, etc.

Figure Type B are a graphic estimate of the effects of the needs/capability matching shown in tabular form in Figure Type C.

4.0 USER REQUIREMENTS FOR LOCATION/RADIONAVIGATION SYSTEMS AND PRESENT AND FORECASTED EXTENT OF USE BY THE YEAR 2000

4.1 INTRODUCTION

Each sub-sector is reviewed in two parts. In part one, the focus is on the requirements, the emphasis is on the desired benefits as well as on the details of the functionality, coverage, availability, reliability and update rate required for the various functions associated with positioning and navigation.

In part two, the focus is on estimating the present extent of use and on forecasting the type and extent of adoption by the year 2000. Present extent of use was derived from data obtained from literature review and through interviews of users and experts. Forecasts pertaining to the type of system which will be adopted and derived from matching needs and desires to system capabilities and by factoring in such elements as intensity of benefits, as well as cost and other institutional barriers. Our forecasts have been discussed with a number of sub-sector and specific radionavigation system specialists and represent what we believe is the best available information at this point.

4.1.1 Urban Transit, Radionavigation Requirements

Description

Urban transit buses operate on fixed routes within pre-determined urban/ sub-urban areas. Barring emergency situations, the main concern of an urban transit system is to deliver an efficient service, conforming as nearly as possible to posted schedules.

Urban transit systems have to cope with a number of important constraints:

- o dense route grid patterns;
- o precise schedules;
- o large numbers of vehicles;
- o shared (at least in part) right of way; and
- o varying traffic conditions.

In order to establish a valid typification for urban transit bus systems interviews were conducted with the managers of three major systems. Figure 9A summarizes the information obtained from the three sources. The paragraphs that follow present a more detailed description of the information obtained through the interviews and a typification of the requirements of the urban-transit sector.

Requirements

In terms of position location and tracking, a distinction can be made between three types of situations: short heading routes, long heading routes and emergencies.

In short heading routes the main concern is to maintain an even spacing between the vehicles to ensure service every so many minutes. If one vehicle slows down, the appropriate solution may be to slow the others down to maintain spacing. Because frequency is high, spacing becomes more important than adherence to specific posted schedule.

In long heading routes, typically those going out into the suburbs, posted schedule adherence is paramount. Any significant departure from the schedule must be identified,

measures must be taken to correct the situation and the public must be informed. In emergency situations, which can range from an on-board disturbance, an accident or even a highjacking (apparently not an unknown situation in some U.S. cities), the information pertaining to the type of emergency and the location (and heading) of the vehicle is required.

To fulfill the above requirements, urban transit operators require systems with position/location, tracking, route guidance and dispatching capabilities. The availability of a monitoring function is important but data can be down-loaded at regular intervals with no need for real time access. The route guidance function takes on a special importance for Urban Transit operators because in many instances they have priority status and can preempt traffic light cycles to remain on schedule.

Present Systems

Present systems are a combination of proximity devices and radio dispatching systems.

In Case 1, each vehicle is equipped with a micro which is polled by the system to determine the vehicle location. On-board micros are connected to the vehicle odometer and sign post receiver. The basic location system is through dead reckoning with sign posts used as "fix" points. Besides location, the system also records boarding and alighting (mat by door) by specific stops. This information is down-loaded at the end of the day. Radio communication consists of four radio frequencies, two are for voice communications with the 250 buses, one is for data and the last is used for voice communications by the supervisory and maintenance staff.

In Case 2, all of the 800+ buses are equipped with a voice radio system. When the driver calls the comptroller the computer flashes the bus ID, the route number, the name of the operator and the scheduled location. The OC Transpo has been testing a location identification system based on passive signals on the bus (to keep costs down) and intelligent sign posts located at key intersections. The sign post reads the bus ID, compares it with a posted schedule and only forwards information if there is a significant discrepancy.

In Case 3, the company is installing an Automatic Vehicle Location and Control system (AVLC). The objective is to achieve better schedule adherence; more flexibility in zones and frequency readjustments and better route management than is available today with inspectors in the streets. With AVLC, inspectors will sit in a dispatch room and manage six whole routes rather than single points. The particular version of AVLC implemented by the TTC is known as CIS (Communication and Information System), it includes a voice link with inspectors, a data link for systems monitoring, a silent alarm and location information.

Location information is based on sign posts and odometers. The odometer reading corrected by the various sign posts is polled by radio every 10 seconds. The information obtained is compared to routes/schedule and the vehicle is displayed on the console according to a specific colour indicating its status.

At present 300 vehicles are equipped with the above described devices; by 1991 all 2200 vehicles in the system will be.

The expected reliability of the system is 96 per cent to 98 per cent; accuracy is 100 feet (at an average 4 km between sign posts).

If a bus is outside the route, it cannot be tracked and the computer will indicate an expected position until an alarm goes off when it fails to show up at the next sign post.

FIGURE 9A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

URBAN TRANSIT

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Urban Transit	Bus	Road	Tracking Monitoring Guidance	65-200	Urban	12	N/A	<1	Signposts & radio	To keep buses on schedule	250
2. Urban Transit	Bus	Road	Positioning Tracking Monitoring Dispatching	N/A	Urban	24	N/A	<1	Microwave signposts & radio	To keep buses on schedule	900
3. Urban Transit	Bus	Road	Positioning Tracking Monitoring Guidance	15-65	Urban	24	96-99%	<1	AVLC (CIS version) Signposts, radio & odometer	Better schedule adherence Better route adjustments & management	2,200
SUMMARY: Urban Transit	Bus	Road	Positioning Monitoring Guidance Tracking Navigation Dispatching	15-65	Urban	24	96-99%	<1	Signposts & radio	To keep buses on schedule	N/A

(1) refer to Section 2.2 for details

(2) number of vehicles operated by respondent.

Benefits Expected or Desired

With improved tracking it will be possible to give passengers waiting at busy bus stops at least 30 seconds advance warning of the route number of the next bus. It is hoped that this advance warning will reduce the time required per stop by 20 seconds, a substantial saving when one considers the number of buses and stops involved.

The sign post based system has an emergency locator (Panic Button), which allows the dispatcher to estimate the scheduled location of a vehicle within half a mile. Locating the vehicle may be more difficult if it is forced off its route.

In the future it will be possible to control traffic lights in order to allow a vehicle to make-up time and go back to its posted schedule.

The system also allows real time schedule variances (or at least delay messages) to be input into the rider information phone line.

Current and Future Location/Navigation Options and Barriers

At present, sign posts are the solution of choice, but they are costly to install and awkward to change.

Satellite-based systems are still considered too expensive but in the long run they may become more attractive (and more flexible) than sign posts. They however, also suffer from interference in urban areas.

Several companies are offering Radiodetermination Satellite Services (RDSS) coupled with LORAN-C, Geostar, Omega or GPS to urban transit operators. Coupled with any satellite system, RDSS is capable of locational accuracy well within the range required of urban transit. It has an update rate of 1 second to 1 minute depending on the exact system being used, tracking capability, and also the capability to accommodate vehicle sub-system monitoring accessible on demand. A 1 second update rate may be too slow for some large dense urban transit systems.

RDSS is 99 per cent reliable or better and is available continuously. Using RDSS with LORAN-C in an urban setting may require adjustments to account for atmospheric and man-made noises.

The switch-over from sign post to satellite technology will be dependent on the transition costs involved and resolution of the interference problem. A problem which is made more complicated by the fact that geostationary satellites tend to have a long "shadow" in Canadian latitudes. A major consideration in the equation is the current heavy vested investment in sign post technology. Technological absorption by the industry will be aided if prices of satellite receivers are reduced and where this technology can be made to complement the existing technology of positioning via proximity devices.

4.1.2 Urban Transit: Present and Future Size of Relevant Fleet

For purposes of this study, only motor buses (1986-10,618 units) and articulated buses (1986 - 86 units) were considered. Given that there is little likelihood that small cities would adopt radionavigation systems to manage their urban transit fleets, only cities of 500,000 inhabitants and above were considered which reduced the starting vehicle numbers to 6,741 motor buses (1986) and 54 articulated buses (1986). According to CUTA only Toronto is expected to expand its fleet of vehicles (300 more vehicles) by the year 2000. All other major Canadian cities are expected to limit themselves to small

amounts of growth.

Needs and Match (See Figure 9C)

Urban transit vehicles do require the monitoring of mechanical functions, but they also require the monitoring of passenger use. Vehicle location is part of this requirement. All systems can supply the necessary location information.

Urban transit vehicles only require on-line vehicle location (Level 2) in emergency situations. Proximity devices and dead reckoning or odometer based devices can supply this information provided the vehicle remains on its route. The real need is for Level 3 and it is made more complex by the fact that buses are expected to keep on schedule (on "long headings") or to maintain time spacing with other buses (on "short headings").

Because of transmission delays to/from the geostationary satellites, Active Systems are inadequate (they also lack the required update rate). At present, proximity devices are still more efficient than either LORAN-C or GPS, but it is possible that in the future, the greater flexibility of GPS may induce urban transit operators to use them for Level 3 functions. Levels 4, 5 and 6 are not a consideration in Canada for non-tracked vehicles before the year 2000.

Type and Extent of Present and Future Use (See Figure 9B)

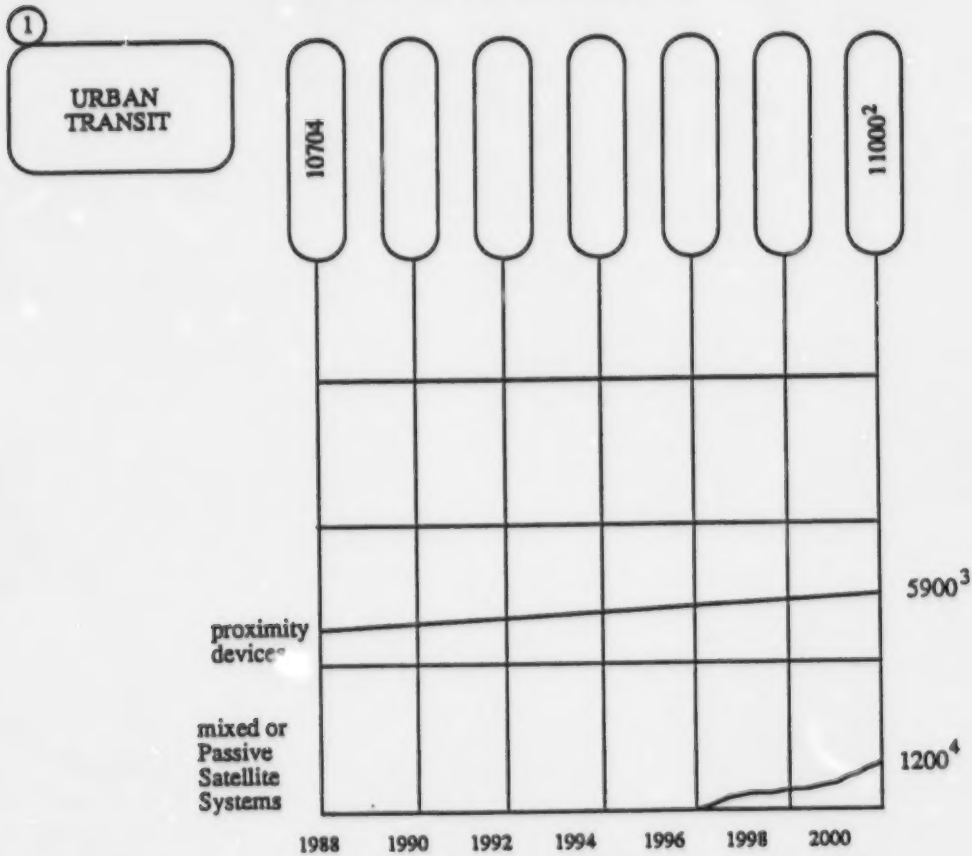
As of 1988, Ottawa, Toronto, Montreal and Vancouver already use a proximity device based Automatic Vehicle Location and Control system and Winnipeg is committed to use the same approach. This leaves Calgary and Edmonton which have made no definite plans. No Canadian city is presently using or planning to use a radionavigation system. One U.S. city is, however, using a LORAN-C based system to feed expected time of arrival to its riders (via a community TV channel).

As a result of the situation described above, it is fairly certain that by the year 2000, a minimum of 5900 vehicles will be under proximity devices control. None of the cities are expected to abandon their present AVL system to adopt a satellite or LORAN-C based system in the next decade.

*Because Edmonton and Calgary are not yet advanced in the selection process for a AVL system, it is expected that they may eventually opt for Passive Satellite and Communication AVL Systems. This expectation is based upon the projections that by the mid 1990s, Passive System (+ differential stations and data/voice communication) will be able to deliver the accuracy required while being more flexible and cost effective than proximity devices. Accordingly, by the year 2000, it is expected that some 5900 urban transit vehicles will be using proximity devices while only 1200 will be using Passive Satellite Systems (see Figure 9B).

FIGURE 9B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



- 1 based on SC.53-215 and 53215 and information supplied by CUTA
- 2 based on a 15% growth in the Toronto fleet and no growth in other fleets
- 3 representing 75% of the fleet in cities over 500,000 inhabitants
- 4 representing Calgary and Edmonton, see accompanying text for details

FIGURE 9C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3	X	2-3
2	X	
1		

4.1.3 Taxis, Radionavigation Requirements

Introduction

In all major Canadian cities taxi companies are in the dispatching business rather than in the fleet ownership and operation business. In some cases the company may lease a number of vehicles to independent drivers (their original fleet), but as a rule the company has no ownership links with respect to the vehicle. It only owns (and rents) the radio and any on board computers used in the dispatching process. The fact that the dispatching service does not own the vehicles has a major bearing on the types of information it requires, or may be allowed to collect.

For purposes of establishing this typification, two major taxi dispatching companies were interviewed. Company 1 manages 700 vehicles while Company 2 operates 472 vehicles. Because of their size they are in the technological forefront of the industry. Taxi companies operating in smaller centers (where fleet ownership is more common) may not have the same requirements. Figure 10A summarizes the information obtained in the interviews. The paragraphs which follow present a more detailed description of the information and a typification of the requirements of the taxi sector.

Requirements

According to the interviewees, positioning would be useful in deciding which vehicle to dispatch, but there are some difficulties in using this type of information.

Vehicle tracking is seen as useful in emergency situations only. The monitoring function is seen as having limited value for the dispatcher, although it may be useful in the case of customer complaints (fast driving, etc.). It is however seen as having value to those vehicle owners who employ drivers. In either case, there is no requirement for on line reporting.

Route guidance would be of interest if traffic and other relevant information was relevant and up to date. It would give drivers an opportunity to avoid traffic congestion.

Navigation aids would be desirable but are probably not cost effective.

Dispatching is the core service provided by the taxi companies. The basic requirements are being met by the Gandalf (or similar data display systems), which provides real-time updates of dispatching information directly to LCD displays mounted inside the taxi. Taxis equipped with such displays nevertheless, retain voice communication capability for emergencies.

A vehicle location/navigation system suitable for use by taxis would need to have regional coverage, 24 hours a day availability, 200 metres accuracy and a short update rate. If automatic, the update rate should be less than one minute; if on demand it should provide the location of any specific vehicle within 10 seconds.

FIGURE 10A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

TAXI

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Taxi	Taxis	Road	Tracking Guidance Navigation Dispatching	65-200	Regional	24	N/A	<1	Computerized dispatching LCD-Gemdale	More efficient dispatching	700
2. Taxi	Taxis	Road	Positioning Tracking Monitoring Guidance Dispatching	65-200	Regional	24	N/A	1-15	Computerized dispatching LCD-Gemdale	More efficient dispatching	472
SUMMARY: Taxi	Taxis	Road	Tracking Guidance Positioning Monitoring Navigation Dispatching	65-200	Regional	24	N/A	<1	Computerized dispatching LCD-Gemdale	More efficient dispatching	N/A

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Present System

Both companies interviewed use a computer assisted data display dispatching system. The system divides the city into cells, any given vehicle can request a position in a given cell provided that it is in that cell and is available. When a call is received it is automatically dispatched to the vehicle in front of the line in that particular cell. The information is displayed on a 32-character alphanumeric LCD one-line screen.

At present, Company 1 has a function on its on-board computer which is intended to prevent the driver from soliciting a priority position in a given cell area before dropping off the current fare. There have been a number of problems with drivers tampering with the system to disable this function and to enable them to "forward book". Company 2 deals with the problem in a different way. A driver requesting a position number at any of the downtown taxi waiting stands has to be in close proximity to that particular stand. Each vehicle is given the number of the vehicle just ahead of him. If vehicle number two arrives before vehicle number one it can report vehicle number one which may be fined.

In emergency situations, the present procedure is to refer to the pick-up point, and the declared destination, to deduce the area or zone where the vehicle should be and ask other drivers to be on the look-out. No other information is available.

The Company 2 system fulfills drivers' navigation requirements through an add-on function of the computerized data dispatch system. If required the driver can request directions from the dispatch computer. The information is limited to 32 alphanumeric characters and focuses on the nearest major intersection.

The cost to equip a vehicle includes \$1,500 for the radio, \$1,500 for the computer, \$700 for the meter and some \$800 for installation. Dispatching fees for Company 1 are \$325 per vehicle per month.

Benefits Expected or Desired

Precise vehicle location information would help to resolve the "excessive" forward booking problem, but it is not at all certain that drivers would agree to pay the additional costs required to install the feature.

A full fledged vehicle location may not be cost effective, an electronic map with zoom-in capability is probably sufficient. Drivers normally know where they are and can find where they want to go if they see it on a map in relation to the nearest major intersection.

An improved mapping system would improve customer service in outlying areas by cutting waiting time by as much as half.

Vehicle tracking would allow much faster action in situations when a driver is in danger and must be reached rapidly.

According to one source, vehicle location, if tamper resistant, would probably be immediately adopted by most U.S. limousine services because their rates of vehicle theft are considerable.

Current and Future Location/Navigation Options and Barriers

Drivers may not be willing to pay additional fees for the additional services. Although drivers are conscious of the advantages of a tracking system in emergency situations, they appear to be more concerned with the "invasion of privacy" aspect (they are independent business persons) and especially about the Revenue Canada implications of the existence of such a track record.

4.1.4 Taxis: Present and Future Size of Relevant Fleet

According to industry sources, it is unlikely that taxi operators outside of Canada's 10 largest cities will require anything beyond a communication/dispatching system before the year 2000. Direct interviews with taxi company operators in all major Canadian cities have resulted in the following estimate of the present size of the fleet:

Toronto (City):	3,100 vehicles
Montreal (City):	5,000 vehicles
Edmonton (City):	1,000 vehicles
Calgary (City):	1,200 vehicles
Ottawa (City):	1,000 vehicles
Halifax (City):	800 vehicles
Winnipeg (City):	800 vehicles
<u>Vancouver (City):</u>	<u>920 vehicles</u>
Total	12,820 vehicles

According to the consensus of interviewees, there are approximately 25,000 taxis registered in Canada (1988).

Again, according to the consensus of interviewees, the total number of taxis in the ten major population centers is unlikely to increase at all from now until the year 2000 but there is a possibility of further concentration into large co-operatives or franchises.

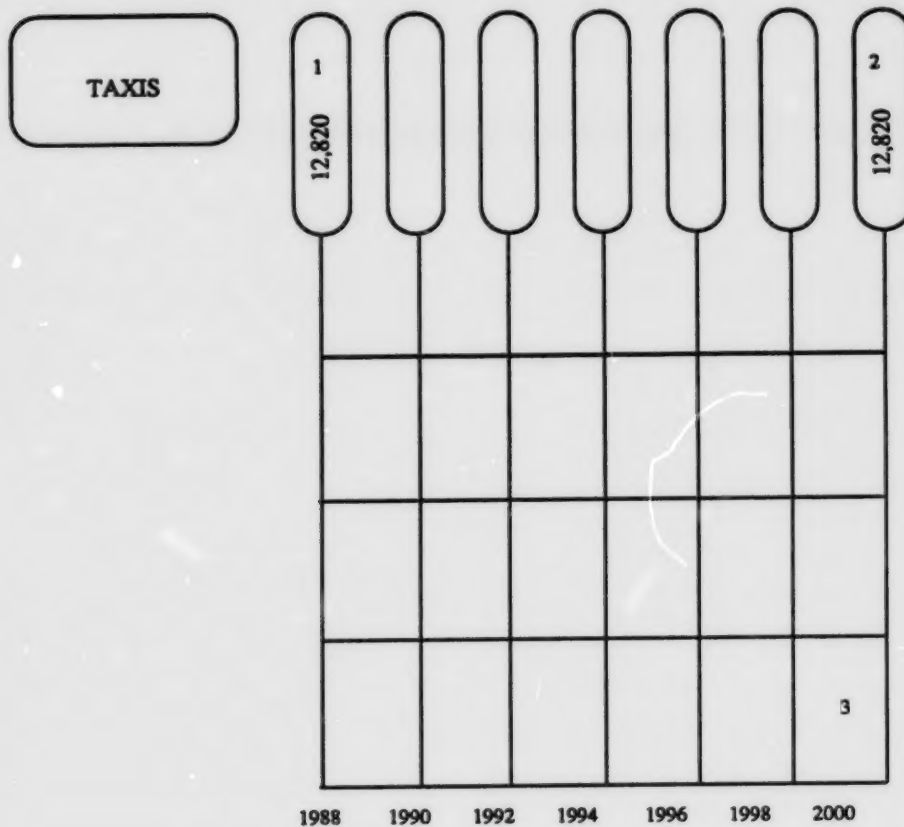
Needs and Match (See Figure 10C)

Taxi companies in major Canadian urban centers are mostly co-ops or franchises. Vehicles belong to the drivers who pay a fee for the dispatching service. There is, therefore, no need for Level 1 service. Taxi company dispatch service operators would like to have a Level 2 service, but since its only use would be to check on cab drivers, it is unlikely that these would be willing to pay for this service (although it would be of considerable use in emergencies). Drivers do not require Level 3, they would appreciate Level 4 type information and some get it by voice from the dispatcher. There is no need for Level 5 or 6. All in all, it does not appear that any system would offer a package of services attractive enough to capture this market in the short or medium term.

Type and Extent of Present and Future Use (See Figure 10B)

All major taxi companies use some form of radio communication (digital or voice) and many have sophisticated systems which allow queuing control. None of the companies contacted makes use of a radionavigation system and none seems to have a requirement which would justify the adoption of such a system in the foreseeable future.

FIGURE 10B
TYPE AND EXTENT OF PRESENT AND FUTURE USE



- 1 based on industry supplied estimates for the ten largest cities in Canada
- 2 no growth expected until the year 2000
- 3 no identifiable number of users

FIGURE 10C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2		
1		

4.1.5 Inter-City Buses, Radionavigation Requirements

Description

The inter-city buses category groups two types of bus services, scheduled inter-city and charter buses, and local tour buses including airport service buses. Scheduled services are mostly concerned with maintaining the posted schedule. To a large extent this is also true of chartered buses.

In order to establish a valid typification, interviews have been conducted with the managers of three representatives of this industry sector. Figure 11A summarizes the information obtained from these sources. The paragraphs which follow present a more detailed description of the information and a typification of the requirements for the inter-city buses sector.

Requirements

All respondents expressed a need for communications capability. Scheduled buses need it mainly to report problems and delays, charter buses would also like to ask for directions and information when they are in a strange city or on a sight seeing tour. A portable system which can be carried along and used in the evenings for reporting and planning would be considered even more desirable.

Both groups expressed a desire for a location/positioning and tracking capability, but did not rate it as a priority requirement.

Vehicle functions monitoring was considered important for maintenance purposes, but there is no need to report these on a continuous basis. Any system which can be downloaded by modem at regular (daily) intervals appeared satisfactory.

Route guidance was considered a very desirable feature in all applications, while need for navigation assistance was expressed only by charter and tour buses.

Dispatching was considered important only by scheduled carriers.

Inter-City buses require a continental coverage, but the accuracy required differs from 200 metres or more on the highway to a 6 to 15 metres while in urban areas (if it is to accommodate computer information systems).

System availability should be continuous but reliability was not perceived as an issue.

None of the respondents expressed a preference for a particular update rate.

Present Systems

The two systems currently in use are tachographs and two-way communications.

FIGURE 11A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

INTER-CITY BUSES

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Inter-city bus	Bus	Road	Positioning Tracking Monitoring Guidance Dispatching	65-200	Continental	24	N/A	N/A	Tachograph	Better dispatch & vehicle maintenance	300
2. Inter-city bus	Tour bus	Road	Positioning Tracking Monitoring Guidance Navigation Dispatching	6-15	Continental	24	N/A	N/A	2-way radio	To simplify job content of driver & tour guide Record keeping	N/A
SUMMARY: Inter-city bus	Bus RVs	Road	Positioning Tracking Monitoring Guidance Navigation Dispatching	6-15	Continental	24	N/A	N/A	N/A	N/A	N/A

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Benefits Expected or Desired

Although the primary purpose of the monitoring system is to accumulate data on vehicle sub-systems for maintenance, guidance and scheduling, it is recognized that it also yields data on the driver's performance as well as data usable in court in case of accident. As such, the benefits of such a system can be substantial, provided the system is reliable and tamper proof.

The requirement for navigation by tour buses is not necessarily tied to the need of the driver to find his/her way, it may also be tied to the requirements of an eventual computerized on-board tourism information system which would supplement or replace the tour bus guide.

Route guidance was considered the most likely to generate tangible benefits. The capacity to avoid traffic congestion was seen as highly desirable by all buses on fixed schedules, especially those doing the airport run. Tour buses were less concerned with the time factor but are still interested in assistance in choosing alternate scenic routes.

Current and Future Location/Navigation Options and Barriers

Currently used technology is a mixture of tachograph and radio. Cellular phones are being considered, but at present they do not offer a location capability. Available alternatives include RDSS coupled with LORAN-C, Omega or GPS. LORAN-C is fully satisfactory in open areas. Satellite-based systems offer high accuracy in positioning and tracking in open area but have limitations in urban areas (especially Canadian). They are highly reliable (99 per cent and more) and will eventually be available continuously. They are further capable of accommodating both vehicle and passenger monitoring devices and communication channels for data transfer and/or exchange. This means that databases can be down-loaded onto the vehicle receiver and later disseminated to the passengers as tour information on a bus tour. Via Geostar, RDSS can also be enhanced with voice capability.

The cost effectiveness of RDSS coupled with LORAN-C, Omega, GPS or Geostar in an inter-city environment has not yet been demonstrated. It is recognized that most inter-city buses' operators would not be able to exploit the full potential of a complete RDSS system and will configure a system to suit their own specific needs. As an example, both sample companies in the survey do not view tracking as a priority function in an inter-city environment. A modular design RDSS system would probably lead to greater adoption in the market because of reduced cost.

One major barrier to the acceptance of on-board route guidance is the type of display to be used by the driver. CRT displays may not be acceptable for safety reasons (they would take the drivers' attention away from the road). Head-up displays would probably be acceptable but this technology is still too expensive for use in civilian vehicles.

Drivers' and union resistance is another potential barrier to the adoption of more advanced navigation equipment by inter-city bus operators; the currently used tachograph has already met with union resistance.

4.1.6 Inter-City Buses, Present and Future Size of the Relevant Fleet (Scheduled Buses)

The Inter-City Buses category includes scheduled inter-city and charter buses. According to Statistics Canada (Cat. 53-215), the number of scheduled inter-city buses has been declining steadily since 1970 while (according to the Ontario Motor Coach Association) the number of charter and tour buses has grown slightly. It is estimated that from 1986 to

2000, the number of Class I and II scheduled carriers will continue to decrease from 20 to 14 reflecting a slow concentration process. The actual number of vehicles is also expected to go down from the 1986 1352 figure to 1000 to 1100 vehicles by the year 2000.

Needs and Match (Scheduled Buses) (See Figure 11C)

If and when Inter-City Buses adopt radionavigation devices it is likely to be because of the route guidance feature (Level 4). Entering and leaving major urban areas without getting bogged down in traffic is considered by Inter-City Bus operators as the major benefit that can be derived from radionavigation. Accordingly, the initial choice of system should favour Active Satellite Systems, provided these develop the volume of business and the data basis necessary to offer an automated optimal route selection service in major Canadian urban areas.

Type and Extent of Present and Future Use (Scheduled Buses) (See Figure 11B)

Since it is not expected that on-line traffic information networks will be available in Canada before the year 2000, it is not expected that this segment will adopt radionavigation systems by the year 2000. Some Canadian buses making scheduled runs to major east or west coast urban areas may, however, be equipped to benefit from services available there.

Present and Future Size of Relevant Fleet (Tour Buses)

The number of full time tour and charter buses in Canada is estimated at around 700 (1988), with a certain percentage of scheduled buses and even school buses being used on a part-time basis. As with scheduled buses, the tour/charter bus industry is heavily concentrated with the top five companies controlling 50 per cent of the vehicles. Growth in the tour and charter sector is expected to be slow and best estimates are for a full time fleet of 800 to 900 vehicles by the year 2000.

Needs and Match (Tour Buses) (See Figure 11E)

Tour and charter buses differ from scheduled units. In the short-term, they have a higher need for navigation (Level 2 - Where am I?) than for actual optimum route selection assistance (Level 4). In the longer term, tour and charter buses are likely to be heavy users of Level 5 or even Level 6 accuracy for the purpose of operating on-board tourist oriented data bases capable of informing passengers on the immediate surrounding sights.

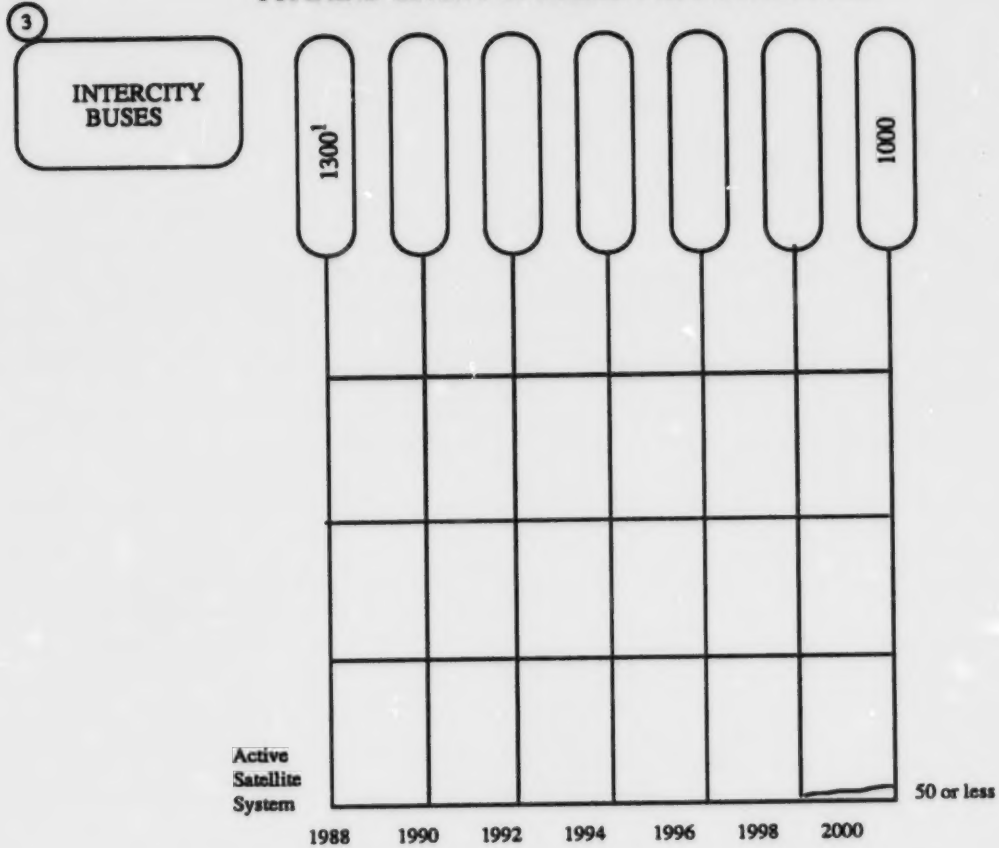
As a result of the above, tour and charter buses should be among the early adopters of Passive Satellite Systems.

Type and Extent of Present and Future Use (Tour Buses) (See Figure 11D)

Up to 25 per cent of tour buses are expected to be equipped with radionavigation devices by the year 2000. This forecast is based on the relative value of the benefits derived in relation to the cost of a GPS receiver (from 1995 on), especially if available as an option with the original equipment. A modern tour bus equipped with video and cellular phone costs more than \$250,000 and the addition of a GPS receiver would not change that price meaningfully. Because tour buses cover wide areas, it is expected that they will favour the GPS technology over the LORAN-C which would be competitive on a more local basis.

FIGURE 11B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



Based on extrapolations from SC Cat no. 53-215 for intercity buses Category 1 (gross revenues above 2M\$) - because of the deficiencies of the original time series data, the above data must be considered an estimate only.

FIGURE 11C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4	X	1
3		
2		
1		

FIGURE 11D

TYPE AND EXTENT OF PRESENT AND FUTURE USE

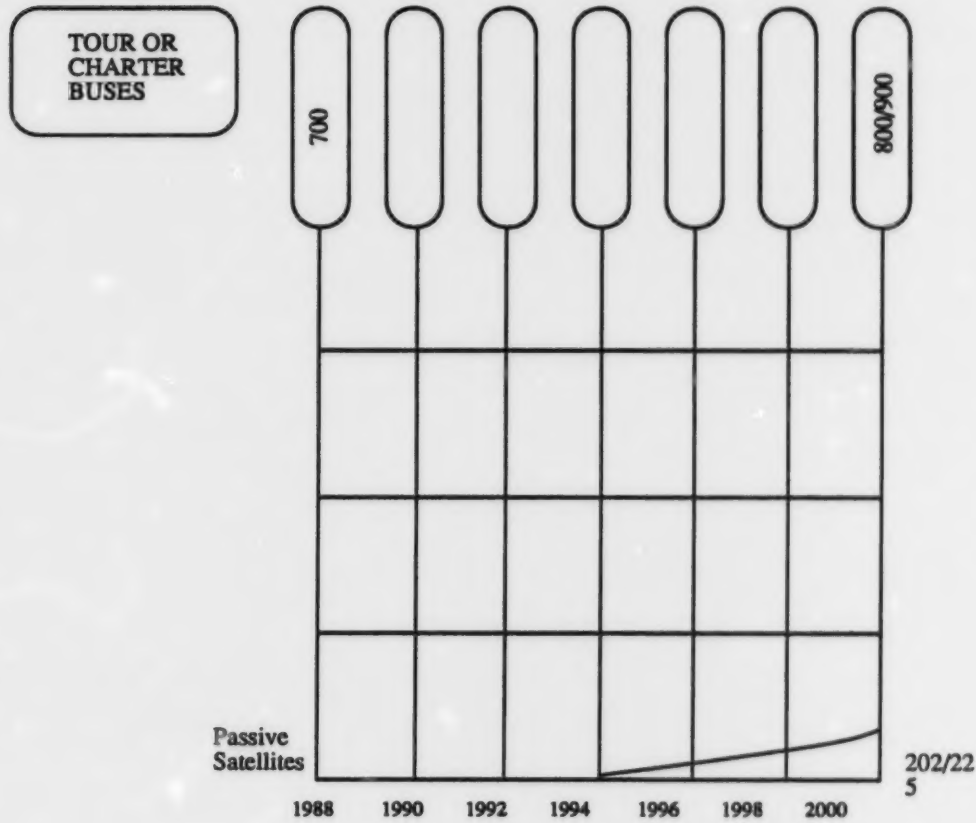


FIGURE 11E

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6	X	2
5	X	2
4		
3		
2	X	
1		

4.1.7 Railways, Radionavigation Requirements

Introduction

The needs of railways are determined by their two major functions, long haul transportation (known as: "Signal Territory") and marshalling yard operations (known as "Dock Territory"). The need for controls in the long haul sections is intensified by the fact that a considerable amount of Canadian rail is single tracked with occasional double tracked by-passes.

A group of North American railway companies, including the major Canadian railways has been developing the standards for a new approach known as the North American Advanced Train Control System (ATCS) which will consist of five upward compatible levels of control sophistication superimposed upon the present centrally dispatched manual block system.

For purposes of establishing the railway typification, four railways were interviewed. The four railways interviewed represent a good cross section of the Canadian railroad industry. Figure 12A summarizes the information obtained from the sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Railway sector.

Requirements

The basic location requirements of railways can be defined as follows:

- o on which track, and
- o where on the track.

No available radionavigation system is capable of discriminating between two parallel tracks. At present, all the railways which have automated tracking systems rely on some form of proximity devices. On the other hand, the question relating to "where on the track" can be answered by most available radio navigation systems because location accuracy is well within the parameters offered by present systems.

As for other transportation systems, railways have a need for vehicle systems monitoring, (locomotive as well as railway cars, and in some cases the actual cargo), but this is a communication related requirement, not a navigation one.

Present Systems

At present, in signal territory, three systems are being used. In the case of short lines, the tracking may be through radio communication. In major lines, the rail and position are tracked with the assistance of transponders or by having the track itself wired to a control board. The transponders are located at key intervals between the tracks and are interrogated by the locomotive, they update the dead reckoning system and the position is reported by radio every several

FIGURE 12A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

RAILWAY

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Railway	Trains	Railway	Positioning Tracking Monitoring Guidance Dispatching	6-15	Regional	N/Av	99%+	1-15	Radio Computer assisted dispatch	Better monitoring of trucks and trains	N/Av
2. Railway	Trains	Railway	Positioning Tracking Monitoring Guidance Dispatching	Which track Position on track	Continental	24	N/Av	16-30	Radio & transponders	Better monitoring of trucks and trains	N/Av
3. Railway	Railway car	Railway	Tracking Dispatching	N/Av	N/Av	N/Av	N/Av	N/Av	Radio dispatching	Better monitoring of trucks & trains	N/Av
4. Railway	Trains	Railway	Positioning Tracking Monitoring Dispatching	N/Av	N/Av	N/Av	N/Av	N/Av	Centralized Traffic Control System Display boards Radio dispatching	Better monitoring of trucks & trains	N/Av
SUMMARY: Railway	Trains Rail cars	Railway	Positioning Tracking Monitoring Guidance Dispatching	Which track Position on track	Continental	24	99%+	1-15	N/Av	Better monitoring of trucks & trains	N/Av

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

minutes. Wired tracks only indicate which track and which section are been used, without supplying position on track information. In dock territory, marshalling information is relayed by radio, with control sheets written down at both ends.

In accordance with plans, the ATCS is supposed to evolve from its present configuration to a level of automation which will eventually allow it to operate without track-side signals (for further details refer to Section 3.2.12).

Benefits Expected or Desired

In the future, railways would like to use more computerized dispatching, in the yard as well as on the main lines. They would like to get away from the present system, which is based on signaling, to a system in which trains are under computer control without need for actual signals along the right of way.

Current and Future Location/Navigation Options and Barriers

The two main barriers to the use of satellite-based radionavigation systems, from the point of view of the railroads are:

- o they cannot discriminate between adjacent tracks;
- o time delay in transmission (as much as 1/2 second each way) is too long.

An American company is presently using GPS as part of a demonstration project. The system is being used for location on track. Track circuits are still being used to identify which track is being used.

As indicated in the ATCS plans, there are at the moment no provisions to switch from transponders to satellites for location purposes.

Note: Because of the ATCS plans, no "extent of use" was undertaken for railways.

4.1.8 Utilities, Radionavigation Requirements

Introduction

Utilities operate a considerable number of vehicles across Canada. They are either private or public; they generally serve a whole province but may operate on a local scale. Utilities perform a number of relevant functions in terms of this study, namely:

- o Installation of new services;
- o Maintenance of the current infrastructure;
- o Meter readings;
- o Respond to client problems;
- o Respond to emergency situations.

For purposes of defining the "Utilities" typification, three major utilities were interviewed. Figure 13A summarizes the information obtained from the sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Utilities sector.

To a large extent, the utilities typification is based on data obtained from one organization because this utility company was found to be well ahead in terms of requirements definition. It is already involved in a location/navigation pilot project

which will involve 300 vehicles and \$10 to \$20 million over the next 10 years.

Requirements

Vehicle location and tracking will be obtained on a digitized map, coordinates will be established via satellite. The information is to be available on-board. Vehicle location would be of some value to the dispatcher, but this would be a low priority function.

Instead of a monitoring function the trucks are to be equipped with an on-board computerized data base containing customer related and power-grid information. Upon receiving a work order the driver will be able to interrogate the data base via specially developed "expert software". The information contained in the work order (number and location of customers affected and type of problem) will allow the system to identify the faulty equipment responsible, its location and its technical and maintenance characteristics. The truck will then be able to "navigate" to that point via map matching, even if the location is remote and weather conditions are bad.

The company is considering installing graphics printers on board to produce throw-away technical drawings as a means of facilitating repair operations.

The route guidance function has not yet been evaluated but it appears to have value for system-wide weather related emergencies, provided the data is more accurate and up to date than that available from the OPP and local police forces.

Signal coverage must extend to the whole province in which a given utility operates. Coverage is especially important in rural and remote areas.

Requirements for signal accuracy are dictated by emergency/weather related needs, and should be from 15 to 65 metres. Reliability should be above 90 per cent. The update rate should be in the five minutes range or better.

Present System

The present system is based on dispatching orders given before departure from base and updates or emergencies being handled by radio (voice).

Benefits Expected or Desired

The main benefits being sought are:

- o faster identification of problems;
- o faster identification of location of faulty equipment;
- o faster access to the faulty equipment; and
- o better technical information available to repair crews without the need to carry awkward three ring binders.

Current and Future Location/Navigation Options and Barriers

As indicated above, utilities are already considering satellite based location and tracking. Communication is still through FM voice and data channels, but could be shifted to satellite based system when appropriate satellites are available.

Although utilities require province wide systems, they are divided into smaller operating areas for dispatching purposes and FM communication may remain a satisfactory solution in most instances.

4.1.9 Utilities, Present and Future Size of the Relevant Fleet

The utility vehicles fleet comprises the vehicles utilized by the phone companies, the electricity companies and the gas companies across Canada. Following a series of 13 interviews with representatives from all three groups of utilities across Canada it became possible to estimate the total number of vehicles (trucks, vans and cars) in this sector as falling in the 45,000 and 55,000 range distributed as follows:

Gas Companies	6,000 $\pm$ 10% vehicles
Hydro Companies	20,000 $\pm$ 10% vehicles
Telephone Companies	23,000 $\pm$ 10% vehicles

According to the same sources, utilities have no plans to expand their total fleets and the consensus is that the overall fleet is not expected to grow by more than three per cent until the year 2000.

Needs and Match (See Figure 13C)

As indicated in the previous report on radionavigation requirements, Hydro Ontario is currently involved in the development of a GPS based system. The initial project will involve 300 vehicles over the next 10 years.

Vehicle location and tracking will be obtained on a digitized map, coordinates will be established via satellite. The information is to be available on-board. The trucks are to be equipped with an on-board computerized data base containing customer related and power-grid information. Upon receiving a work order the driver will be able to interrogate the data base via specially developed "expert software". The information contained in the work order (number and location of customers affected and type of problem) will allow the system to identify the faulty equipment responsible, its location and its technical and maintenance characteristics. The truck will then be able to "navigate" to that point via map matching, even if the location is remote and weather conditions are bad.

Ontario Hydro is considering installing graphics printers on board to produce throw-away technical drawings as a means of facilitating repair operations.

The route guidance function has not yet been evaluated but it appears to have value for system-wide weather related emergencies, provided the data is more accurate and up-to-date than that available from the OPP and local police forces.

Type and Extent of Present and Future Use (See Figure 13B)

On the basis of the above, it can be stated that utility companies have essentially two needs, Level 5 (navigation) and Level 4 (route guidance) for emergency situations. Since there is no need for continuous dispatching, nor for tracking of vehicles, function 2 is not required. Function 3 is not necessary and function 6 is not regarded as relevant.

Given the concentration of needs around Level 4 and 5, and the fact that coverage must include northern areas, the system of choice appears to be GPS, as confirmed by Hydro Ontario's test program.

Given the known capabilities of the GPS system to deliver the desired benefits and the relatively low cost to add new vehicles to the system once it is fully operational, it is expected that Hydro Ontario will become a significant GPS user (at least 20 per cent of its total fleet of 10,000 vehicles) by the year 2000. It is also expected that other utilities will

follow the Hydro Ontario example (although none has yet developed plans to do so). This projection is, in part, based on the general perception that utilities seem to be fairly quick to adopt successful innovations pioneered by other Canadian utilities.

It is, therefore, expected that up to 6000 vehicles operated by utilities will be equipped with radionavigation systems by the year 2000 (20 per cent of Hydro Ontario and 10 per cent of the others) and that this number will climb very rapidly thereafter. In fact, if the Hydro Ontario test proves very successful early on, the estimate would have to be reviewed by a factor of at least two and possible three.

FIGURE 13A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

UTILITIES

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Utilities	Trucks & Off road	Road Off road	Positioning Navigation	16 - 65	Provincial	24	95%	1-5	Manual scheduling Automated mapping	To aid in routing, repairs & emergencies	150
2. Utilities	Large & small trucks	Road	Guidance Dispatching	N/A/V	Provincial	24	N/A/V	N/A/V	Radio	Flatter services to the public including emergencies	20
SUMMARY: Utilities	Trucks & Off road	Road Off road	Positioning Guidance Navigation Dispatching	15 - 65	Provincial	24	N/A/V	1-5	N/A/V	Flatter response to emergencies & repairs	N/A/V

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

FIGURE 13B

TYPE AND EXTENT OF PRESENT AND FUTURE USE

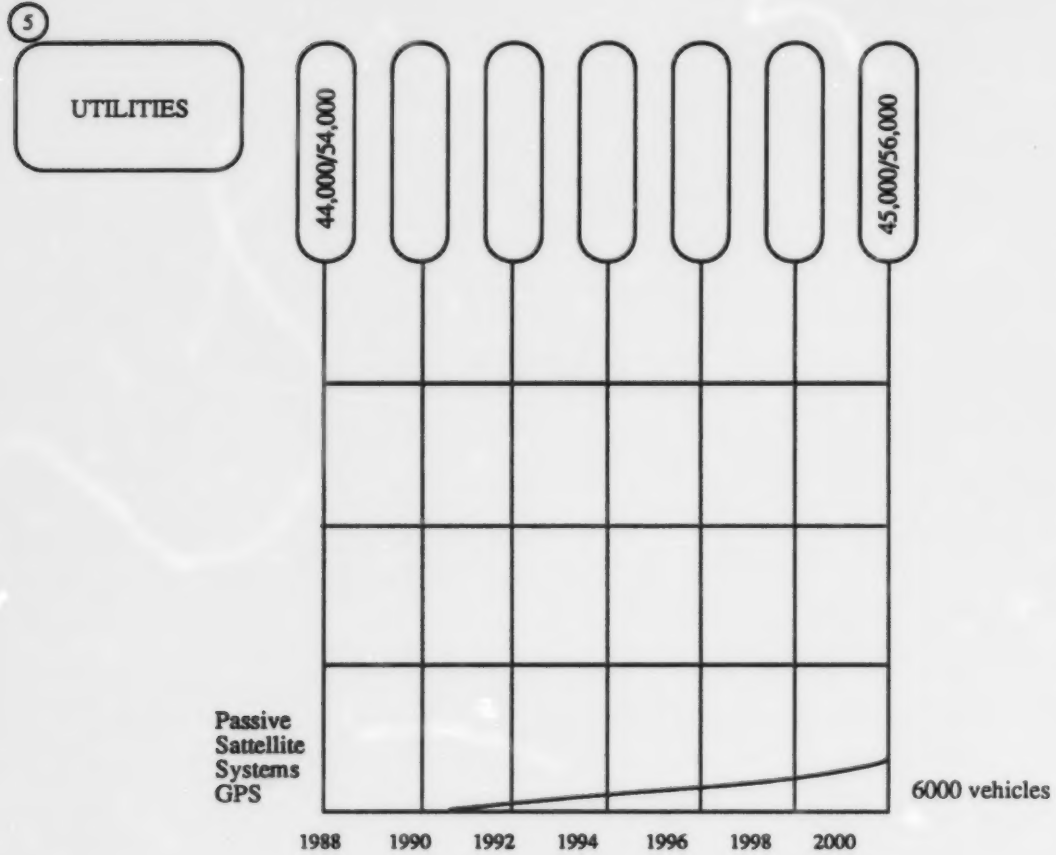


FIGURE 13C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5	X	2
4	X	2
3		
2		
1		

4.1.10 Public Safety and Emergency Vehicles, Radionavigation Requirements

Introduction

The public safety and emergency vehicles typification includes the following services:

- o Provincial police;
- o Ambulance services (rural and urban);
- o Municipal police;
- o Fire department;
- o Towing companies; and
- o Dangerous goods tracking.

Figure 14A summarizes the information obtained from the various interviews. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Public Safety and Emergency Vehicles sector.

Requirements

The position location requirement function is generally linked to some type of emergency situation. For example, police forces would like to be able to locate their vehicles quickly, even if the officer is unable to communicate. Ambulance services would like to be able to spot any in-transit ambulance near an emergency in order to be able to re-route it. Tow operators would like to know the whereabouts of their vehicles on standby for faster dispatching. Given the nature of emergency services, vehicle location must be updated fairly frequently which is tantamount to vehicle tracking.

Both the police and fire departments would like to see dangerous goods tracked and monitored at all times. They do not want to assume this responsibility but would like to be alerted on an exception basis if monitoring indicates some potential problem (pressure, temperature etc.), or if vehicle is in an unauthorized area.

A track record giving time and location would also be of help in establishing responsibilities.

For a towing company, location and tracking capability would make it easier to select the best located vehicle for the job, and more importantly to give the clients a more realistic estimated time of arrival (ETA).

The fire and police departments would also like to have rapid on the spot access to precise information about the nature of the dangerous goods involved in any given accident. At present this is not always feasible (or at least not fast enough). In many cases the authorities first have to identify and track down the shipper, sometimes half a continent away.

Other than for dangerous goods, vehicle functions monitoring is not a high priority feature for any of the emergency services, only ambulance services indicated that

FIGURE 14A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

PUBLIC SAFETY AND EMERGENCY VEHICLES

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELI- ABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Ambulance- urban & rural	Ambulances	Road	Monitoring Dispatching	65-200	Provincial	24	99%+	N/Ap	Map	Faster response to emergencies	560
2. Ambulance- rural	Ambulances	Road	Positioning Tracking Guidance Navigation Dispatching	200+	Regional	24	99%+	<1	Radio	Faster dispatch & response rate	N/Ap
3. Ambulance- urban	Ambulances	Road	Positioning Tracking Monitoring Guidance Navigation Dispatching	6-15	Regional	24	99%+	<1	N/Ap	Faster response	250
4. Police	Car Trucks Off Road & others	Road Off Road Portable	Positioning Tracking Guidance Navigation Dispatching	15-65	Provincial	24	99%+	<1	Telephone & Radio	Faster response Time	3,500
5. Fire - Dept.	Large Trucks	Road	Positioning Guidance Dispatching	65-200	Provincial	24	99%+	On Demand	Telephone & Radio	Faster response time	N/Ap
1. Towing	Tow trucks	Road	Positioning Tracking Guidance Navigation Dispatching	15-65	Regional	24	N/Ap	<1	2-way radio Cellular	Faster dispatch & response Route guidance	20
SUMMARY: Ambulance	Ambulances	Road	Positioning Tracking Monitoring Guidance Navigation Dispatching	6-15	Provincial	24	99%+	<1	N/Ap	Faster response to emergencies Better use of available vehicles	N/Ap

(1) refer to Section 3.2 for details
 (2) number of vehicles operated by respondent.

they would benefit from information on vehicle status, i.e., is it available or in service. Patient monitoring on the other hand is considered very desirable. It requires a data and voice link with the destination hospital.

Route guidance is not considered a priority, although it is seen as possibly useful in some occasions in urban areas. As a general rule, ambulance drivers, fire truck drivers, and police officers know their district thoroughly. In the case of fire, the vehicle operators receive routing information as well as details about the building, its contents etc. on the call printout before leaving the station. All the emergency services keep track of road work, parades and any other occurrence likely to affect traffic, they do not however receive real time detailed traffic updates.

There is some discussion aimed at installing an extra printer or screen in fire chief cars to facilitate access to additional information available at the fire station.

Some towing companies transport mobile homes over long distances as well as tow buses and tractor trailers across Canada and the USA. Route guidance would be most useful in performing these additional functions, especially in connection to high and wide loads. Providing the capability to avoid temporary width restrictions due to road work could save substantial time on long distance deliveries.

One provincial police force requires provincial coverage up to latitude 52.3 degrees North, others require provincial or regional coverage. Accuracy requirements vary, the OPP and urban ambulance services had the highest accuracy requirement from 6 to 15 metres. Towing companies would like an accuracy between 15 to 65 metres in town and within five miles out of town, while others indicated that they would be satisfied with a 65 to 200 metres accuracy or even less. Availability must be continuous and reliability must be in the 99 per cent range or better. Update rate requirements are in the one minute range.

Present Systems

There are always a number of ambulances in transit around a major urban area. These are ambulances coming from outside the area or returning to their base. When traveling through a given area, these ambulances are available to respond to emergencies but the dispatcher does not always know exactly where they are. Given a location/tracking system these could be better utilized.

At present the same provincial police force is still using its original radio system installed in 1947. The system links 1500 users comprised of cars, aircrafts, motorcycles, vessels and hand held portables. The system is being replaced over the next four years, at a cost of \$ 109,000,000 by a Motorola microwave system. The new system is expected to extend the communication coverage to 2000 users.

Since mid June 1988, the one of the major cities in Canada has been equipped with a 911 emergency phone service which automatically traces the address of the caller. The usefulness of the automatic caller tracing is being hindered by the increasing use of cellular phones.

The ambulance service in the same city is considering a vehicle monitoring, computer dispatch, electronic map matching system for its ambulances for 1991. No details are currently available.

Towing companies use radio to cover surrounding areas and phone in for long hauls. One towing company interviewed in this study is using cellular phones in its trucks to facilitate contacts with clients; it is also considering installing fax printers (\$2,700) to transmit work orders while the driver is out of the cabin.

Benefits Expected or Desired

At present, road maps, marine maps and air maps use different systems of coordinates. A common map system using latitude/longitude, degrees and minutes and metric location, and thus usable by surface vehicles, small craft and aircraft would permit a much tighter integration of emergency services.

In larger cities such as Toronto where the number of emergencies is high, a dispatching system capable of locating the vehicle closest to a given emergency call without delay would be able to offer a more efficient service. This increased efficiency should translate into a lower requirement for additional units.

With respect to ambulances, the greatest benefit would be, as indicated earlier, the possibility of effectively using the services of vehicles in-transit.

For police forces, the most important benefit is related to the possibility of locating an officer in trouble.

For towing companies, one of the important advantages of a computer-assisted data based dispatch system is that it would no longer require the dispatcher to use the voice radio frequency. This simple change would provide much greater security for the dispatching system and inhibit the ability of competitors to monitor a company's frequencies (and try to cut into its business).

Current and Future Location/Navigation Options and Barriers

Emergency vehicle dispatching needs have the same technological solutions as taxis, with the added proviso that some emergency vehicles require location and tracking, a function which is not essential to taxis. Therefore, emergency vehicles have several options, depending whether they are urban or rural.

For urban areas, the options are LORAN-C or RDSS type system or GPS or any satellite-based location system. Either would be satisfactory once problems related to urban area related interference and "urban canyon" effects are dealt with.

For the rural coverage, a currently available option is RDSS coupled with LORAN-C. This option does not preclude the use of a satellite-based system, it only recognizes that in the short term LORAN-C receivers are less costly and that the LORAN-C signal, where available is free of charge.

Given that tow trucks are being outfitted with cellular phones, it is conceivable that towing companies would attempt to use the same equipment for location purposes. This option has the advantage that present cellular technology is already capable of locating a vehicle within five miles which satisfies the rural requirements. In addition, work being undertaken by a Montreal based company, may result in a breakthrough with cellular becoming available for more accurate urban positioning.

4.1.11 Public Safety and Emergency Vehicles, Present and Future Size of the Relevant Fleet

The emergency vehicle group includes:

- o Provincial police forces;
- o Ambulance services (rural and urban);

- o Municipal police forces;
- o Fire departments; and
- o Towing companies.

According to interviews, the total number of vehicles operated by the provincial police forces are:

OPP:	1300
QPP:	1000
RCMP:	7000

While local police forces were estimated at 6000 vehicles.

According to the 1986 Canada Consensus of Road Motor Vehicle Registrations, the number of fire trucks and ambulances was 204,000. Finally, the number of tow trucks was estimated at some 20,000 vehicles by the Canadian Touring Society.

As a result, the total number of emergency vehicles in Canada is estimated at 240,000 units.

According to the interviewees, the consensus is that emergency vehicle numbers should grow by no more than 5 per cent by the year 2000.

Needs and Match Analysis (See Figure 14C)

According to the Part I study, emergency vehicles have a requirement for vehicle location status and ID which are presently being fulfilled through data/voice communication.

A Level 2 capability would enable more efficient dispatching.

Emergency vehicle drivers are generally trained to know the territory they operate in and rarely require directions to go from point A to B (when in need, they obtain this information from the dispatcher). On the other hand, emergency vehicles would benefit considerably from a Level 4 capability (automated route selection) since this would allow them to reach the site of the emergency sooner.

Type and Extent of Present and Future Use (See Figure 14B)

There are two types of emergency vehicles; those operating in (relatively) small urban areas (which can be covered with one or two FM transmitters), and those operating in large rural areas where this is not feasible. Emergency vehicles operating in urban areas have two options; GPS and LORAN-C. Currently, the LORAN-C is the dominant technology. Several LORAN-C systems are being implemented in the U.S. including the recently completed Detroit system which covers 798 emergency vehicles of all kinds (police, ambulances, fire trucks). The Detroit system (by II Morrow) uses LORAN-C for location tracking and navigation and an FM network for communication. Dispatching is made possible by a high polling ratio (once a second or so). The accuracy of the LORAN-C has been increased considerably by adding a receiver to the dispatcher's computer and by using the drift of that unit as a differential station. Although there are no actual operating systems (emergency related), recent tests indicate that GPS is capable of offering high accuracy in urban areas provided that it is coupled with a dead reckoning or odometer based device to cover the "shadow" and multipath areas. Currently, there are

no known tests involving the use of GEOSTAR for the dispatching of urban emergency fleets.

For higher level functions such as automated/optimized route selection, all the above systems are on an equal footing as they all depend on external inputs to be able to determine the best route.

Given the nature of emergency services, it is probable that some police forces (provincial and urban) and a number of major urban area ambulances and fire departments will adopt a radionavigation system before the year 2000. The probability is that early adopters (5000 to 10,000) would adopt the LORAN-C technology while later adopters are more likely to choose (the, by then, competitive and more accurate) GPS technology (2000 to 4000). No significant numbers of GEOSTAR adopters are forecasted before the year 2000.

Given that the need for vehicle location is greatest in urban areas, the short-term forecast would favour LORAN-C. In fact, existing systems used by emergency vehicles (in the U.S.) are almost all of the LORAN-C type. The extent of adoption forecast is made more difficult by the fact that adoption timing may be dictated as much by technical as by budget and political considerations. By the late 1990's, the situation will be even more competitive with GEOSTAR entering into the fray with high ratio update and GPS resolving the urban canyon problem and adding communication capabilities.

FIGURE 14B
TYPE AND EXTENT OF PRESENT AND FUTURE USE

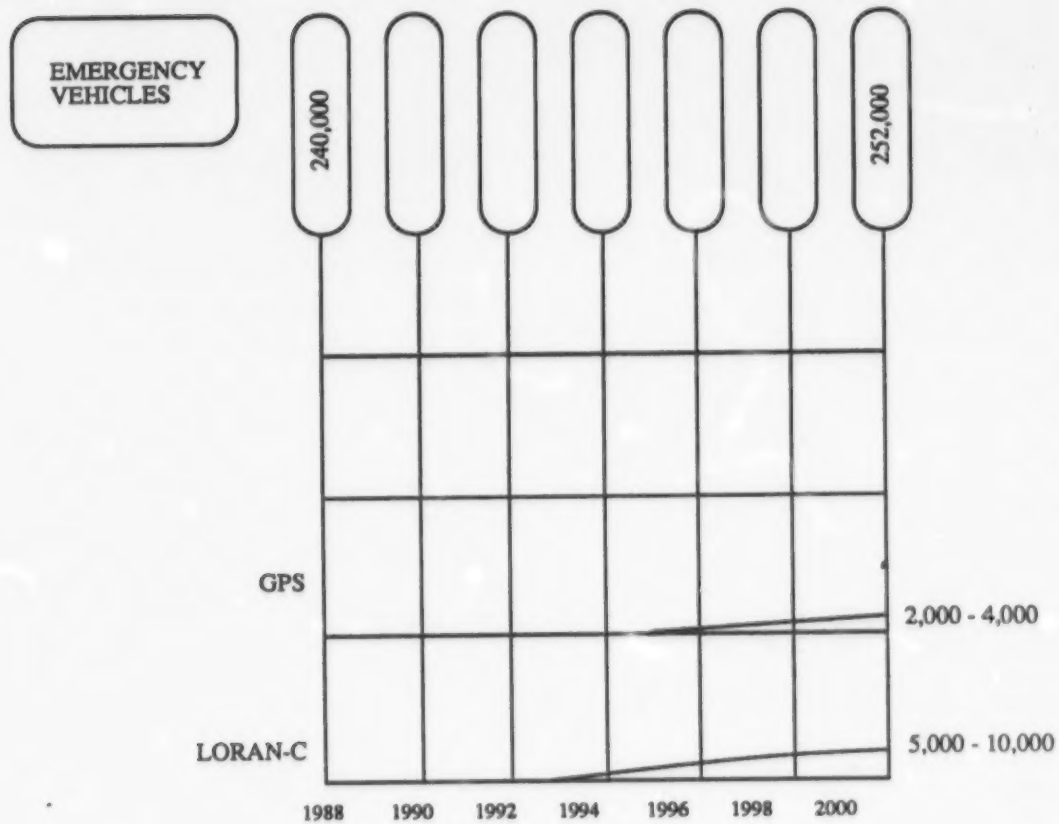


FIGURE 14C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4	X	2
3		
2	X	1 - 2 - 3
1		

4.1.12 Canada Post, Radionavigation Requirements

Introduction

Canada Post operates on two levels: the first is concerned with inter-city shipping of mail and parcels; the second with the actual pick-up and delivery of mail, parcels and Priority Post.

Inter-city transport is performed using contract private sector carriers. Some 2000 vehicles are involved in this aspect of the operation. They are owned and operated by private operators and Canada Post's involvement is limited to insuring that the clauses of the contract are adhered to and that pick-ups and deliveries are on schedule. There are substantial penalties for delays.

Canada Post does not interface directly with the drivers, all communications are with the contractor's dispatcher.

Canada Post owns the almost 5000 vehicles used in mail and parcel pick-up and deliveries in urban areas. Eighty per cent of the vehicles operate in the 20 major Canadian cities while the remaining 20 per cent operate in another 200 smaller centres.

Pick-up and deliveries can be segregated into two categories: the fixed routes where the delivery is made in a predetermined sequence and the area responsibility where the vehicle operator has the flexibility to roam a given area. The first type of route is used for normal mail pick-up and deliveries while the second one is used in parcel and Priority Post pick-up and deliveries. Figure 15A summarizes the information obtained from Canada Post. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Canada Post sector.

Requirements

The requirements are not the same for long haul transport and P&D, they also vary between fixed routes and area responsibility.

Long haul transport

At the present time Canada Post knows where a transport truck is supposed to be according to the schedule, it does not have any independent means to locate or communicate with the truck. Obtaining real time independent (not from the contractor's dispatcher) information on vehicle location would be desirable.

Updating the vehicle location information every 30 to 60 minutes would be sufficient, closer tracking would probably not be necessary.

Given the geography of Canada, route guidance would probably not be useful as an on line feature, but a record of traffic conditions would be helpful in verifying delay reports.

Monitoring, as well as actual dispatching, is more a concern of the contractor than of Canada Post.

FIGURE 15A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

CANADA POST

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELI- ABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Canada Post	Trucks Cars	Road	Positioning Tracking Guidance Dispatching Navigation	200+	Continental	24	N/A	1-15	Radio	Ability to monitor more closely operations of contract carriers (eventually re-route)	5,000 in- house & 2,000 contract

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Canada Post does not consider navigation as a necessary function, although it recognizes that individual contractors may have a different opinion. (Yankee Transport, one of Canada Post's contract carriers is said to be considering a satellite assisted navigation system.)

For vehicle location purposes, Canada Post would consider 50 miles on the open road and one mile in urban areas as acceptable. Coverage would have to be continental and availability 24 hours a day.

Pick-up and Delivery

Canada Post does not expect to use any vehicle location device in relation to its fixed routes P&D for at least the next decade (there are no plans beyond that). There is a short term interest in relation to parcel post and Priority Post (representing 10 to 20 per cent of the fleet).

Over the next five years Canada Post would like to monitor vehicle functions, with no need for an on line system. After this period it may become viable to look at other performance areas, some of which may require real time access.

Route guidance is not considered a requirement. Traffic considerations are generally not an issue.

Dispatching is presently done by FM radio. Unless there is an urgent call for a pick-up, routing is done before departure and dispatching needs are limited.

Whatever system is put in place it is unlikely to go beyond the 20 basic major cities. The level of accuracy required would be in the 65 to 200 metres. Signal availability should be 8 am to 7 pm. The update factor desired is two to five minutes.

Present System

As indicated, there is little presently available in terms of on line navigation or communication. This is mainly due to the fact that long haul transport is under contract and that P&D is planned (and optimised) at the postal station, leaving little requirements for on line changes.

Benefits Expected or Desired

With respect to long haul transport, the major expressed benefit to be derived from an independent tracking system would be the ability of Canada Post to monitor more closely the operations of its contract carriers.

With respect to P&D, including Priority Post, Canada Post stressed that at present, given the present environment and available technologies, it favours route optimization over on the air real time dispatching. It would however be interested in more system monitoring capabilities to develop more real time route management.

Current and Future Location/Navigation Options and Barriers

For vehicle location and monitoring, RDSS operating on satellite fixes or LORAN-C is probably the most appropriate currently available option. Communications could continue via an FM voice channel or be switched to a more efficient data channel.

The option open to contract carriers are covered in the trucking typology.

Canada Post is considering the possibility of developing a capability to track its contract carriers vehicle. The idea is that there would then be an opportunity for increased efficiency through enroute rerouting.

4.1.13 Canada Post, Present and Future Size of the Relevant Fleet

Canada Post related sources include some 2000 privately owned long-haul inter-city delivery trucks operating under contract and some 5000 mail and parcel pick-up and delivery vehicles. There are no plans to expand significantly the contracted fleet or the P&D fleet until the year 2000.

Needs and Match Analysis (See Figures 15C and 15E)

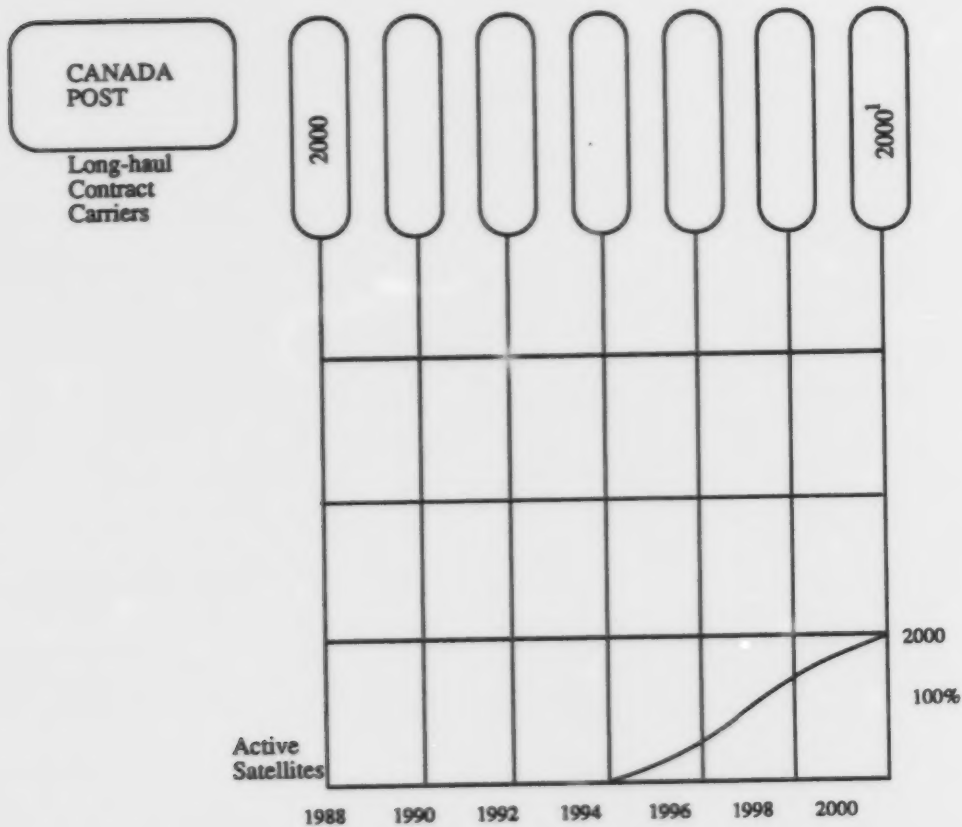
Because en-route recruiting represents an opportunity for increased efficiency, it is expected that Canada Post will implement a tracking and rerouting (Level 2) policy for its contracted long-haul fleet before the year 2000. It is not expected that Canada Post will install its own on-board equipment but that it will have its computer system interface with the contractor's tracking system. It is, therefore, likely that Canada Post will make it a condition of contract that vehicles be equipped with a tracking and communication device.

With respect to its 5000 mail and P&D delivery vehicles, there are no plans to go beyond monitoring vehicle functions (Level 1) for the 80 to 90 per cent of the fleet used on fixed routes. With regard to the vehicles utilized for Priority Post in the top 20 Canadian urban centers, the expressed need is for enhanced communications only since each operates in a well known, well defined area which appears to make dispatching or route guidance superfluous (Canada Post does not feel that it would be cost efficient to attempt to computer optimize writings within each cell). As a result, it is not expected that Canada Post will adopt any radionavigation equipment for its P&D fleet until after the year 2000.

Type and Extent of Present and Future Use (See Figure 15B and 15D)

It is expected that by the year 2000, all the long-haul trucks under contract to Canada Post (approximately 2000) will be equipped with an Active Satellite system.

FIGURE 15B
TYPE AND EXTENT OF PRESENT AND FUTURE USE



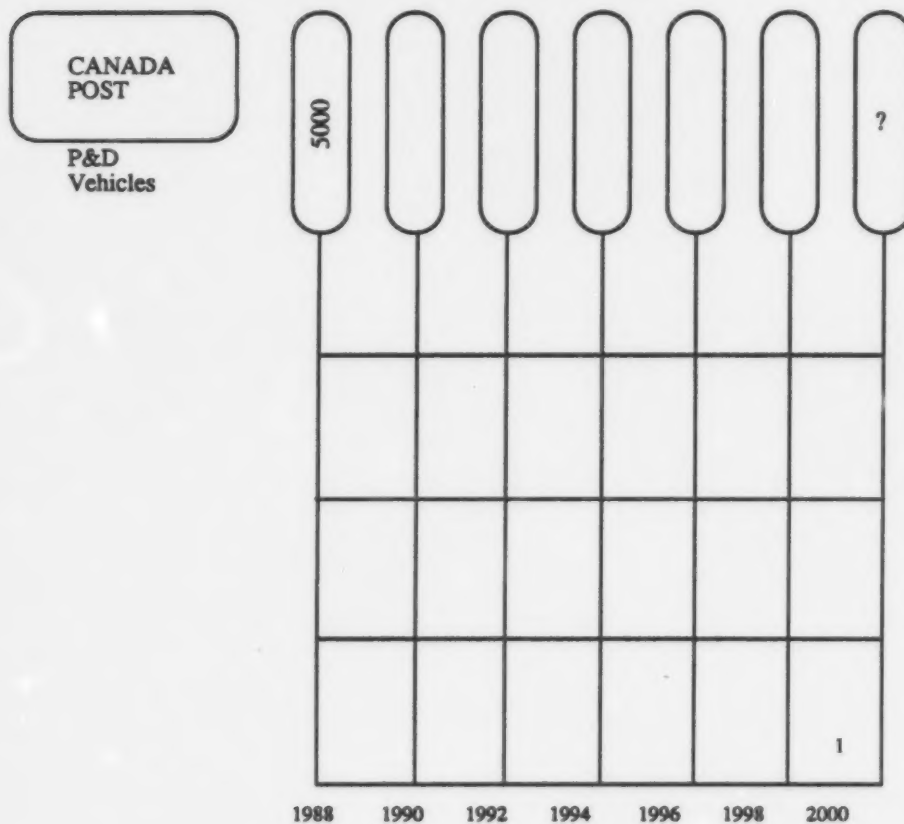
- 1 Canada Post has no long-term projections for Contract Carriers vehicle numbers. Because of the benefits of en route rerouting, it was estimated that the total fleet may not grow substantially.

FIGURE 15C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2	X	1
1	X	

FIGURE 15D

TYPE AND EXTENT OF PRESENT AND FUTURE USE



1 No radionavigation equipment expected by the year 2000.

FIGURE 15E

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2		
1	X	

4.1.14 Correctional Services, Radionavigation Requirements

Introduction

Correctional Service has two basic needs, one is related to the transfer of prisoners, the other has to do with the potential tracking of parolees. Figure 16A summarizes the information obtained from Correctional Services. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Correctional Services sector.

Requirements

The transfer of inmates requires that vehicles be tracked to facilitate their location in cases of emergencies. It also requires the real time monitoring of some vehicle functions and especially that of the status of the inmates. The route guidance function could be of occasional assistance, navigation and dispatching being of little use.

Present System

At present the federal Correctional Service uses no location device either for parolees or for vehicles. According to Correctional Service the BC Correctional system is considering testing Presence Verification bracelets.

Benefits Expected or Desired

According to Correctional Service, a portable tamper proof device capable of offering limited (controlled) roaming as well as tracking would have a market of more than 2000 units at the federal level alone (provided that it was allowed by the courts and not considered an infringement of privacy or suffer from other such impediment).

Current and Future Location/Navigation Options and Barriers

With regard to the surveillance of parolees, there are already several systems in use and under consideration. One type of system requires that the parolee remain in the proximity of a low power transmitter while carrying a non removable transponder in a bracelet. As long as the transmitter receives the signal from the bracelet it assumes that the carrier is within the allowed 150 metres and advises the central computer accordingly. Other systems require the parolee to insert a key in a slot at random intervals determined by the device. Others still rely on random calls which must be answered by the parolee. None of the above systems allow any mobility to the parolee (generally under "house arrest") and none assist in locating the parolee if he fails to respond.

FIGURE 16A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

CORRECTIONAL SERVICES

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL ABILITY HRS/DAY (1)	RELI- ABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Correctional services	Prisoner Cars	Fixed base Road	Location Tracking Guidance Monitoring	16 - 65	National	24	N/A	1-15	Short range Transmitter Antennas	Monitor progress of prisoner transfers Check on prisoner locations	N/A

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

4.1.15 Correctional Services, Present and Future Size of Relevant User Group

As indicated in the Part 1 study, a portable tamper-proof device capable of offering limited (controlled) roaming as well as tracking, would have a market of more than 2000 units at the Federal level alone, provided that it was allowed by the courts and not considered an infringement of privacy or suffer from other such impediments.

Needs and Match Analysis (See Figure 16C)

Radionavigation/location systems based on Active Satellites, have the potential to offer "controlled roaming" and tracking (Level 2) which is a considerable improvement on the presently available "bracelet" system which offers only a "house arrest" option. Given the appropriate type and size portable unit, it becomes possible to allow the user to roam certain corridors at certain specified time periods while remaining confined at other times. This would, for instance, allow the user to go to work or school in the morning (along a known path) and even to take pre-authorized trips (it would, therefore have equivalent characteristics to a Level 4 service). Only if the user strayed from the space/time corridor would the system trigger an alarm. Even then (as opposed to current systems) contact would be maintained and location and arrest would be greatly facilitated (provided the system is such that it operates in densely built-up areas and inside buildings).

The characteristics of the system are such that it would probably find use in the monitoring (controlled roaming) of inmates on day passes or early release (paroles) and might give rise to new alternative (e.g., community services, etc.) programs to incarceration.

Controlled roaming appears to have several cost as well as technical advantages which make it an attractive option but there are presently no "official" estimates of potential use by the year 2000 or before. This is apparently due to two major factors:

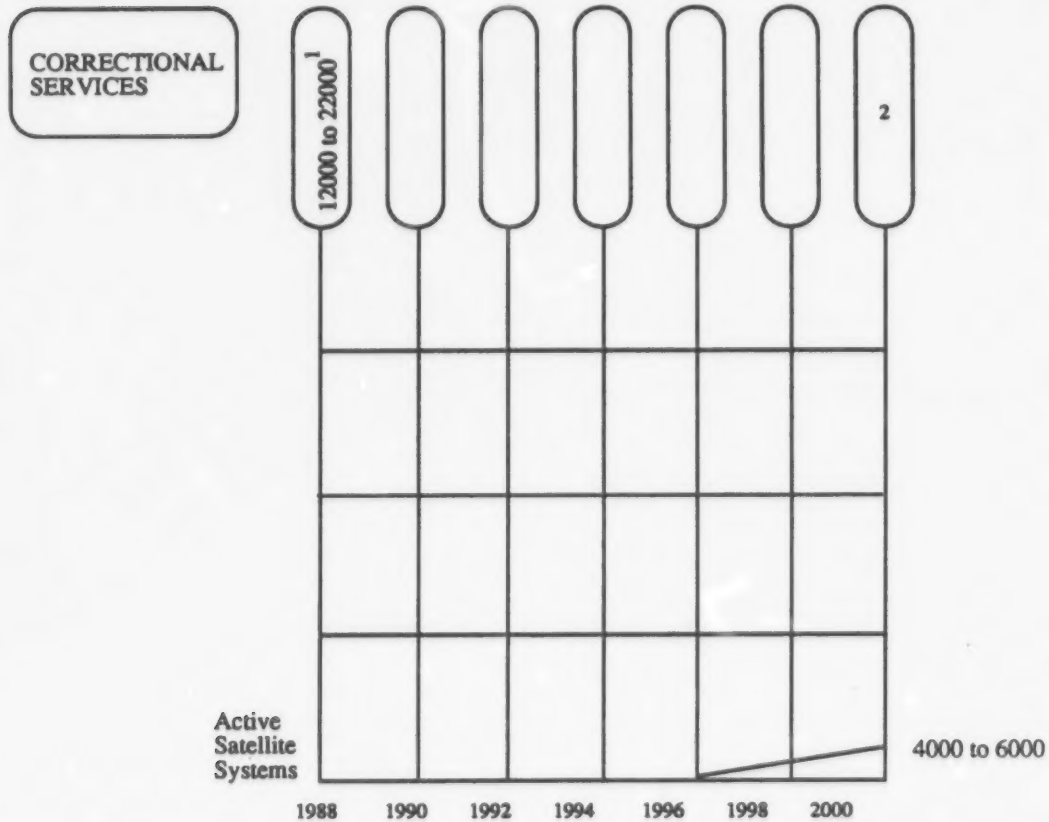
- o the appropriate equipment is not yet available; and
- o Correctional Services are still concerned with the legal aspects surrounding the use of such devices.

Type and Extent of Future Use (See Figure 16B)

Based on the size of the eligible incarcerated population in federal and provincial jails, on the probable evolution of portable equipment and assuming no major legal barriers, we have estimated that by the year 2000, 4000 to 5000 inmates will be involved in some form of "controlled roaming". We, therefore, project a potential Active Satellite receiver base of 2000 units for the whole of Canada by the year 2000 (assuming rotation in users). This forecast could be affected downward by court challenges and upward by a change in penal philosophy from incarceration towards controlled roaming. One key technical element yet to be resolved is the development of a portable unit capable of operating without interruption in all urban settings.

FIGURE 16B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



- 1 Eligible incarcerated population, Federal 2000 (Correctional Services),
- 2 Provincial 10,000 to 20,000 (estimates. No available projections, 1988 figures used.

FIGURE 16C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4	X	- 2 -
3		
2	X	- 2 -
1		

4.1.16 Local Government, Radionavigation Requirements

Introduction

The typification on local government is based on interviews with the equipment/fleet managers of two government organizations. As a rule, municipal government requirements have three basic types of needs:

- o to keep track of heavy equipment;
- o to keep track of snow plows; and
- o to keep track of passenger type vehicles.

Organization 1 operates 25 dump trucks used mostly for snow plowing, 225 pick-ups and 50 cars. Some of the pick-ups are used by game wardens. Organization 2 operates 20 vehicles, mostly for snow plowing and municipal repairs. Figure 17A summarizes the information obtained from the two sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Local Government sector.

Requirements

Vehicle location does not appear to be a priority requirement, although it is recognized that it would have control advantages. Game wardens would like to have some vehicle location equipment for emergency situations, but only if the equipment was portable. Such equipment is now becoming available both for LORAN-C and satellite based systems.

Vehicle tracking was seen as useful for snow plowing, snow removal and salt and sand distribution. Monitoring of vehicle functions was seen as desirable, but no real time monitoring is necessary. Dispatching is a requirement which is already being met via FM radio voice network. Route guidance would be useful during weather disturbances. No navigation requirement was identified. The desired coverage would be regional; accuracy 65 to 200 metres, availability, continuous, and update rate one to 15 minutes.

Present System

At present the only available function is dispatching by radio.

Benefits Expected or Desired

As indicated, major benefits would be during inclement weather and other emergencies.

Current and Future Location/Navigation Options and Barriers

Current needs do not indicate a high priority for a location/navigation system. If one were to be installed, it would have to take into consideration the urban environment and would likely adopt the same solutions available to other prospective users in urban settings with the same accuracy requirements.

FIGURE 17A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

LOCAL GOVERNMENT

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Government fleet	Cars Trucks Off road	Road Off road	Positioning (or Location) Dispatching	65-200	Regional	24	N/A	1-15	Radio	Faster location of snow plows in emergencies	300
2. Public works	Snow removers Heavy Equipment	Road	Positioning Tracking Monitoring Guidance Dispatching	200+	Urban	N/A	N/A	16-30	N/A	Better service to public	20
3. Local Govt	Trucks Snow removers Heavy Equipment	Road Off road	Positioning Tracking Monitoring Guidance Dispatching	65 to 200	Regional	24	N/A	1-15	N/A	Better service to public	N/A

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent

4.1.17 Local Government, Present and Future Size of Relevant Fleet

According to the Canadian Association of Municipalities, Canada's local governments employ an estimated 103,000 vehicles, mostly of three types:

- o construction and maintenance heavy equipment;
- o snow removal; and
- o passenger and other vehicles.

It is expected that the fleet may grow to 108,000 vehicles by the year 2000.

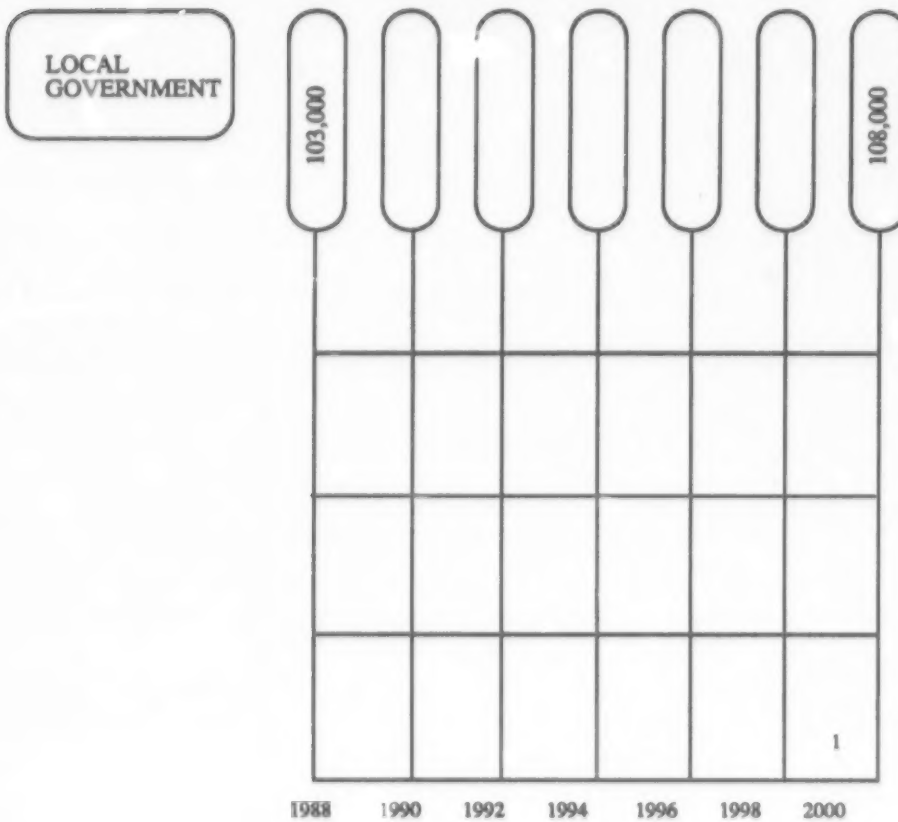
Needs and Match Analysis (See Figure 17C)

At present, the primary need is communication for dispatching purposes. Besides some emergency location (Level 2) capability requirement by game wardens and during natural disasters and other emergencies, no radionavigation requirements were identified. As indicated by most interviewees, if any system is implemented it is likely to piggy-back on the one used for emergency vehicles.

Type and Extent of Present and Future Use (See Figure 17B)

No present use of radionavigation systems was identified. There are no realistic expectations that local governments will adopt radionavigation systems in any significant numbers by the year 2000.

FIGURE 17B
TYPE AND EXTENT OF PRESENT AND FUTURE USE



1 Forecast is for 0 users by the year 2000

FIGURE 17C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2		
1		

4.1.18 Surveying, Radionavigation Requirements

Introduction

The survey typification was obtained from two sources, both of which are government based organizations. As a result, this typology may not cover the requirements of small commercial surveyors. Figure 18A summarizes the information obtained from the two sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Surveying sector.

Requirements

Surveyors have two requirements, one is to get to the site and the other is to affect very precise location measurements. The approach requirements are especially problematic in the north for which the use of the GPS system is being considered.

With respect to position location surveyors require a portable system capable of great accuracy and reliability. The second order accuracy requirement is 2 cm or better per 200 metres in urban settings and 10 to 20 cm in rural settings. The vertical component of location is even more stringent. The second order vertical is 1 cm or better in an urban area and 2.5 cm in a rural area. The first order vertical accuracy requirement is 3 mm per 500 metres in an urban area and less than 1 cm per 10 km in a rural area. Reliability should be at least 99 per cent plus, but availability is not a problem.

The coverage of the system must of course be national.

Update rate is not an issue. Longer periods (30 minutes to 3 hours) are acceptable for more precise readings, except at Active Control Systems (ACS) (see below) where a 5 to 15 minutes update rate would be desirable.

Present Systems

At present, there are a number of different GPS receivers in use, namely:

- o TI 4100 receivers;
- o Wild - Magnavox; WM 101
- o Norstar 1000; and
- o Trimble

The Transit system has also been used successfully for surveying since the early 1970's.

FIGURE 18A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

SURVEYING

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELI- ABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Surveying	N/Ap	Portable Resource mgt.	Positioning	Very high	National	24	N/Av	16-30	GPS, Omega	Simple user operation & high precision	N/Ap
2. Surveying	N/Ap	Portable Off road	Positioning	Very high	National	24	N/Av	16-30	Geographical reference grid	Simple user operation & high precision	N/Ap
SUMMARY: Surveying	N/Ap	Portable Off road	Positioning	Very high	National	24	N/Av	16-30	N/Ap	Simple user operation & high precision	N/Ap

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Current and Future Location/Navigation Options and Barriers

One of the options being considered is the establishment of Active Control System stations. An ACS station would consist of a GPS receiver operating continuously in an unmanned mode. The information supplied by the station, supplemented with meteorological information is then radioed back to a central processing point and distributed to users for differential control use. It is expected that the availability of ACS stations would allow surveyors to use a common frame of reference for all measurements and to achieve much greater homogeneity in the measurements themselves.

4.1.19 Surveying, Present and Future Size of Relevant User Group

The present and future number of potential users (public and private) of radiolocation devices for the purpose of surveying in Canada can only be estimated within a fairly broad range. The present number of users (equipment) is estimated at less than 200 with estimates for the year 2000 at between 500 and 800 (depending on the extent of use by private users. The above estimates should be considered as indicative only.

Needs and Match (See Figure 18C)

All indications are that surveyors will use GPS receivers. Increased accuracy will be achieved through accumulation of readings and/or with the assistance of ground based differential stations.

Type and Extent of Present and Future Use (See Figure 18B)

As indicated above, it is expected that all 500 to 800 receivers in use by the year 2000 will use the GPS system. It is expected that all the TRANSIT band equipment will be phased out before the year 2000.

FIGURE 18B
TYPE AND EXTENT OF PRESENT AND FUTURE USE

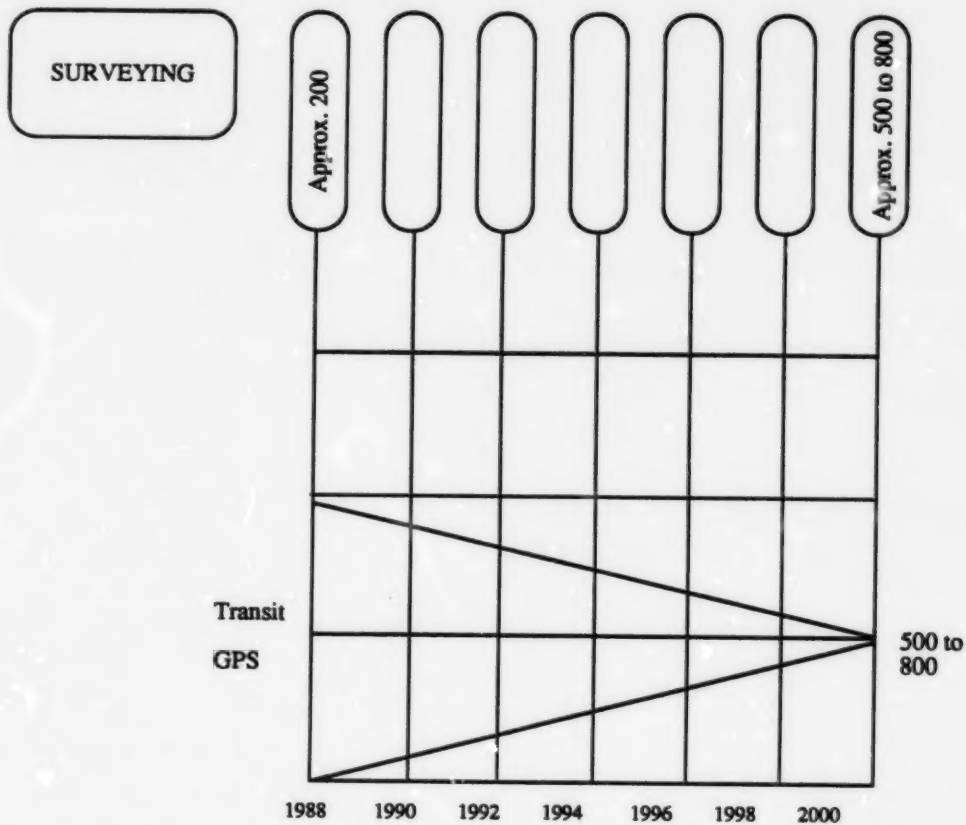


FIGURE 18C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2	X	2
1		

4.1.20 Courier Services, Radionavigation Requirements

Introduction

Couriering involves the pick-up, handling and final delivery of mail or parcels. The main service provided by couriers is speed and reliability. There are a number of different types of courier services, some are purely local, others are inter-city or even international. The interest of courier services in the location/navigation function can best be highlighted by the fact that, one of the premier US courier service has bought II MORROW, a major producer of LORAN-C based equipment.

Company 1 (3000 vehicles) was selected and interviewed as a representative courier company. Information was also obtained from the literature. Figure 19A summarizes the requirements of this sector.

Requirements

The basic requirement is to enable the dispatcher to contact vehicles or runners in order to direct them for additional pick-ups, or to inform them of pick-up cancellations. Communication is also used by drivers in distress or to contact drivers in family emergencies. In Canada, Company 1 operates on an area basis, as such it does not require information about the location of a vehicle as the vehicle is assumed to be in its assigned area. Company 1 does dispatch on a vehicle location basis in some of the major US metropolitan areas such as New York.

Monitoring of vehicle functions, as well as data required for payroll purposes are becoming requirements.

Route guidance is not considered necessary because drivers know their area extremely well and it is unlikely that a computer system could do much better in optimising their route. On the other hand, drivers would appreciate traffic information if it was up to the minute. Traffic information was considered very important on certain runs such as airport runs.

Dispatch is the key to the whole operation. The dispatching is evolving from a voice based method to a digital (3 LCD lines, 20 digits each), and is expected to go eventually to a full CRT.

Present System

At present Company 1 is running a demonstration project involving a small Toronto terminal with 50 vehicles. The system is somewhat similar to the dispatching system used by a taxi company based in Ottawa. Vehicles leave the depot in the morning with a full load of deliveries and a list of known pick-up calls. During the day, as more pick-up requests are received they are coded as to a specific area and communicated to the appropriate driver. When necessary the vehicle returns to the depot to pick up additional parcels to be delivered.

The system monitors a number of operating information and transmits it to the dispatch office at five minute intervals.

FIGURE 19A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

COURIER SERVICES

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS	ACCURACY IN METRES	COVERAGE	AVAILABILITY HRS/DAY	RELIABILITY	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Courier service	Couriers	Road	Monitoring Tracking Guidance Dispatching	N/Av	Regional	24	N/Av	1-15	Technograph & radio	En route communication to increase delivery efficiency	50

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent

Other functions required or desired from the system are:

- o Vehicle identification. This feature is intended to assist the depot gate guards in denying access to unauthorized vehicles.
- o On-board client data base. This data base would help drivers speed up pick-ups and deliveries by giving them specific information on who to contact for what and exactly where for each client.
- o Wand connected to driver belt. This laser bar code reader device is used to log parcels in and out of the system to facilitate timing and tracking.

Benefits Expected or Desired

As indicated earlier, the major benefits sought by the courier companies are related to increasing their ability to achieve speed and reliability, in the most cost effective way.

Current and Future Location/Navigation Options and Barriers

At present, Canadian couriers are not requiring the vehicle location, tracking or route guidance functions. As such their problem is chiefly one of communication, not of radionavigation.

4.1.21 Courier Services, Present and Future Size of the Relevant Fleets

According to interviews with five national courier services, the most likely to be early adopters of radionavigation devices, their present fleet includes approximately 8,155 vehicles.

Although these do not represent nearly the totality of couriers operating in Canada, they have been chosen as the representative population for purposes of this study because they are normally ahead of local operators in terms of use of technology.

According to the same sources, the size of their fleet is expected to increase by approximately 30 per cent by the year 2000 (10,000 vehicles).

Needs and Match (See Figure 19C)

Level 1 (off-line) monitoring of vehicles and drivers for a variety of functions including payroll preparations are becoming important requirements, but this does not favour any of the systems under study.

Several U.S. courier companies operate on-line dispatching of vehicles in dense urban areas and are equipping their vehicles with vehicle location devices (UPS is using LORAN-C). According to these same companies, the requirement does not yet exist in Canada where they are still operating on an area basis. It is expected, however, that before the year 2000 Level 2 requirements will be common.

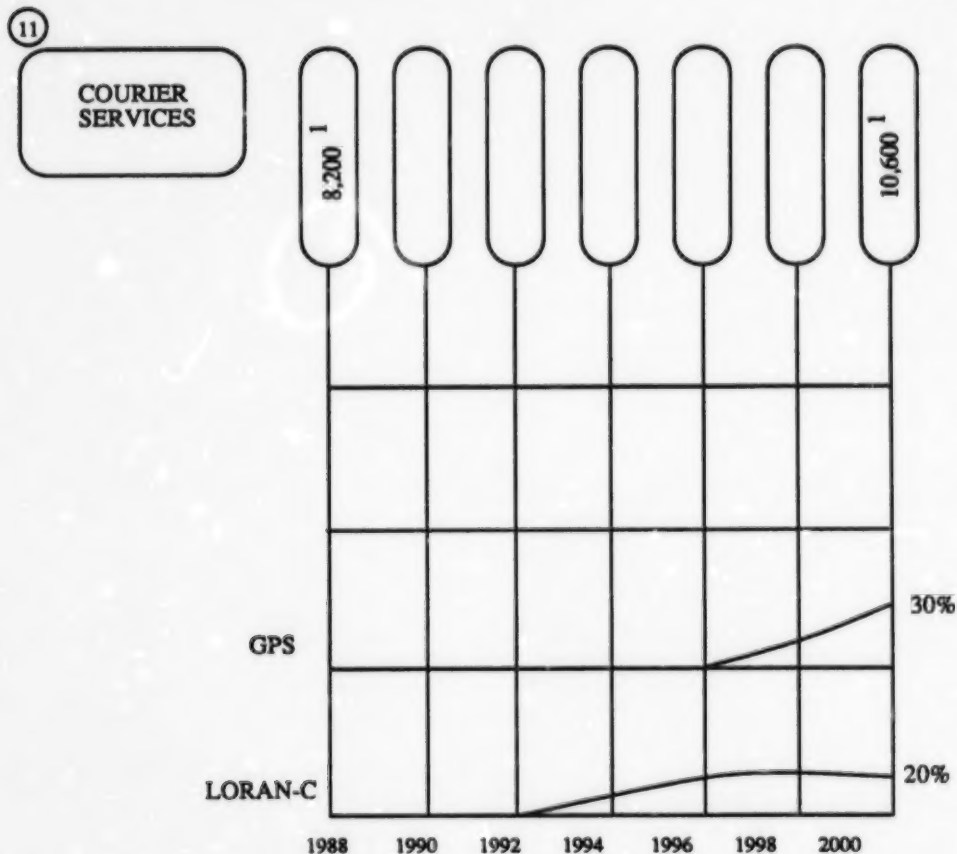
Type and Extent of Present and Future Use (See Figure 19B)

At present, no Canadian courier company is using a radionavigation system. Given that UPS is using LORAN-C in some U.S. urban areas, it is to be expected that some form of radionavigation system will be adopted in Canada before the year 2000. Given the competitiveness of the business, adoption by one major competitor should rapidly result in a majority of large couriers adopting a similar (or competitive) system. If GEOSTAR

had a much higher update rate, it would probably be favoured. As things stand, the advantage rests with an appropriate communication system. In the short-run, LORAN-C is favoured because it has a higher relative (and therefore repeatable) accuracy in urban areas while GPS is still hindered by shadows and multipath. On this basis, we project a 50 per cent penetration of radionavigation systems by the year 2000 with an initial domination (20%) by LORAN-C and a faster growth of the GPS system after 1995 (up to 30% by the year 2000).

FIGURE 19 B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



(1) Representative number (see previous page)

FIGURE 19C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2	X	2-3
1	X	

4.1.22 Commercial Trucking, Radionavigation Requirements

Introduction

There are two functional aspects to commercial trucking:

- (1) pick-ups and deliveries or P&Ds, and
- (2) long distant hauling.

Although performed by different vehicles, both functions may be provided by a single trucking operator. P&D is accomplished by both small and large trucks, coverage does not usually extend beyond a given region. Long distant hauling by comparison is performed predominantly by large trailer trucks with networks extending across the entire North American continent. The most frequent origins and destinations outside Canada are to the northeastern, western and southern parts of the United States.

In addition to recognizing the two distinct functional aspects of the industry, it is also necessary to differentiate between four categories of cargo:

- General, non-hazardous cargo;
- Valuables;
- Hazardous products; and
- Perishables.

The basic trucking typification is intended to represent all of the above sub-sectors. When substantial differences exist they have been dealt with in the appropriate sections.

In establishing a valid typification for commercial trucking, interviews have been conducted with six representative companies covering all the above areas. Figure 20A summarizes the information obtained from the six sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Trucking sector.

Requirements

With the exception of one private delivery fleet manager who felt that their present system based on predetermined delivery routes was fully satisfactory (cargo is loaded according to a given route and delivery must follow that route) all others indicated that intermittent vehicle location/positioning would be desirable. For general cargo hauling, information on vehicle location every hour or half hour appears satisfactory, armoured trucks and dangerous goods carriers had more stringent requirements.

The two groups most interested in vehicle tracking were the armoured trucks operators (Company 4, 100 armoured vehicles) and the hazardous goods carriers (Company 3, 60 trucks and Company 5). Armoured truck operators would like to track their vehicles closely all the time to be in a better position to react

FIGURE 20A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

COMMERCIAL TRUCKING

(1) refer to Section 3.2 for details
(2) number of vehicles operated by respondent.

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Commercial trucking - general	Large trucks	Road	Positioning Tracking Guidance Monitoring Navigation Dispatching	65-200	Continental	24	99%+	16-30	Loran C, Geostar	50% reduction in vol. of communications 2% increase in loaded miles factor	660
2. Commercial trucking - general	Large trucks	Road	Positioning Tracking Guidance Monitoring Navigation Dispatching	1,600 (or 1 mile)	Continental	12	N/Av	N/Av	En route phone in	Better routing & faster delivery	176
3. Commercial trucking - general	Large & small trucks	Road	Positioning Tracking Monitoring Guidance Dispatching	65-200	Regional	12	N/Av	N/Av	Manual	Silent witness Better driver identification	60
4. Armoured trucking	Armoured trucks	Road	Positioning Tracking Guidance Navigation	15-65	Regional	24	N/Av	16-30	FM radio	Greater security due to better precision & monitoring	100
5. Transporting hazardous products	Large & small trucks	Road	Positioning Tracking Monitoring Guidance Navigation Dispatching	6-15	Continental	24	N/Av	N/Av	Tachograph with automated summary/recapitation reporting capability	Better loading & safety	N/Av
6. Commercial trucking - general	Large trucks & trailers	Road	Guidance	N/Av	N/Av	N/Av	N/Av	N/Av	N/Av	N/Av	1000
SUMMARY: Commercial trucking - general	Large & small trucks	Road	Positioning Tracking Monitoring Guidance Dispatching Navigation	65-200	Regional Continental	24	N/Av	16-30	N/Av	Better loading & faster delivery	N/Av

in case of an assault or other emergency. Hazardous goods carriers want to be certain that their vehicles are not infringing on municipal hazardous routes designations.

Most respondents expressed interest in the monitoring function, the armoured vehicle operators are interested in tracking time spent on each pick-up and delivery as it is the basis for their charges. Other operators would like to monitor a variety of vehicle functions. None of the expressed needs had however a requirement for real time monitoring.

Route guidance was considered a desirable function by most respondents but it was seen as a service to be used on occasions rather than on a continuing basis. Hazardous goods carriers and wide, heavy and high load carriers were the most interested. The self navigation function was considered interesting but of limited use. If available at a low cost as part of a package, it would be useful when the truck is looking for an unfamiliar pick-up or delivery point.

Company 6's delivery fleet is the one least dependent on dispatching. All goods to be delivered are loaded in a certain order and deliveries are made in the reverse order. The route is optimised before loading. Fleet performance is insured by the fact that drivers are compensated on the bases of the number of pieces delivered. If drivers require instructions they phone from a client's house. As a result, two-way radios have been removed from trucks.

All other operators use dispatching. For P&D it is usually done via voice radio, long distance trucks are mostly dependent on phone in, but Company 1 is now linked to GEOSTAR (only one way, from truck to dispatch for the moment).

Present Systems

Present systems used by trucking operators range from manually devised schedules at the start of the day to en-route phone in, radio communication, and since very recently, to LORAN-C and GEOSTAR-based systems.

Company 1 has just inaugurated a GEOSTAR LORAN-C based system which allows them to locate their vehicles once every hour. By late 1988, the system should be in place in all 660 vehicles and vehicle location should be available every 30 minutes. The accuracy of the system outside of urban areas has been tested at 100 metres, the reliability being in the 99.5 per cent range. The company indicates that its system has some problems in urban and industrial areas because it is LORAN based. Another limitation is the lack of northern coverage. However, this is not an issue at Company 1 because they do not operate in the north.

The major advantage of the GEOSTAR system is that it requires no processing to be done in the vehicle itself. This means that the GEOSTAR receivers are relatively inexpensive to acquire and to maintain. According to Company 1, the capital cost required to equip each truck in a large fleet is in the \$1,000 to \$1,200 range and the monthly operating cost is in the \$50 range.

In the fall the company is planning to equip its trucks with on-board fax printers with a view to printing the bill of lading on the spot.

Benefits Expected or Desired

With better navigation aids, truck deliveries can be speeded up and, more importantly, the loaded miles factor can be increased (one respondent indicated expectations of a 2 per cent gain in its loaded miles factor, which would represent a substantial benefit and a

very fast pay back). The added load factor is due to the fact that by being able to locate and contact trucks on the road it becomes possible to add more in transit loading business.

Up to date vehicle location information reduces the need for radio and telephone communication by 50 per cent or more. This in itself could represent a considerable saving (enough to cover a portion of the location navigation service).

Better information on vehicle and cargo will allow better cargo tracking, including direct computer tracking by the shipper.

Better information on weight, width and height restrictions (route guidance) would be beneficial to trucks carrying the types of loads affected by these restrictions.

Enhanced vehicle sub-system monitoring will improve vehicle maintenance and overall fleet management.

Carriers of valuable or hazardous products stand to benefit from closer load status monitoring. More precise positioning and tracking of these vehicles may in any case become mandatory.

Hazardous goods carriers expect that the availability of location navigation and monitoring services will enhance their safety record. They would however like to have a "grab along" hand held unit in each truck so that, in case of emergencies, the driver can contact them without having to stay in the cab to do so.

Current and Future Location/Navigation Options and Barriers

Company 1 is already using a LORAN-C and GEOSTAR configured system for its navigation/communications requirements. The system has been in place for only a few weeks, but it already appears to be meeting expectations. An alternative for commercial trucking operators would be to have a modular RDSS coupled with a satellite positioning system and possibly a voice or data link via a communication satellite. It would have less communication limitation. For the moment its major drawback would be cost.

4.1.23 Commercial Trucking, Present and Future Size of the Relevant Fleet

According to Statistics Canada, (Stats. Can. No. 53-221 and 222), there were 559 class 1 freight carriers (revenue over \$2 million) in Canada in 1985. According to the same sources, class 1 carriers represented roughly 70 per cent of the total for hire trucks available in Canada (108,943/157,209). Statistics Canada tables also indicate that about 60 per cent were general freight vehicles while five per cent were bulk liquid carriers, four per cent were dump trucks, seven per cent forest product carriers and 25 per cent "other commodities" carriers.

For purposes of forecasting the use of radionavigation systems, it would be desirable to break down commercial trucking in terms of:

- o general non-hazardous cargo;
- o valuables; and
- o hazardous products

because the two latter categories have a much higher probability of adoption. However, this breakdown is unavailable and forecasts have been based on available non-

disaggregated figures. Forecasts were also based on unadjusted 1985 figures for lack of reliable class I projections to the year 2000.

Needs and Match (See Figure 20C)

As indicated in 2.3.12 of the Part I study, commercial trucking companies generally consider Level 1 (monitoring off-line) a requirement. Operators also expressed a strong requirement for Level 2 capability for vehicle location (valuables and dangerous goods) and enroute dispatching (all categories). Some carriers involved in oversized load would also benefit from a Level 4 "assisted" route selection. Some operators also indicated that they would welcome a Level 5 capability for use in unfamiliar areas.

Type and Extent of Present and Future Use (See Figure 20B)

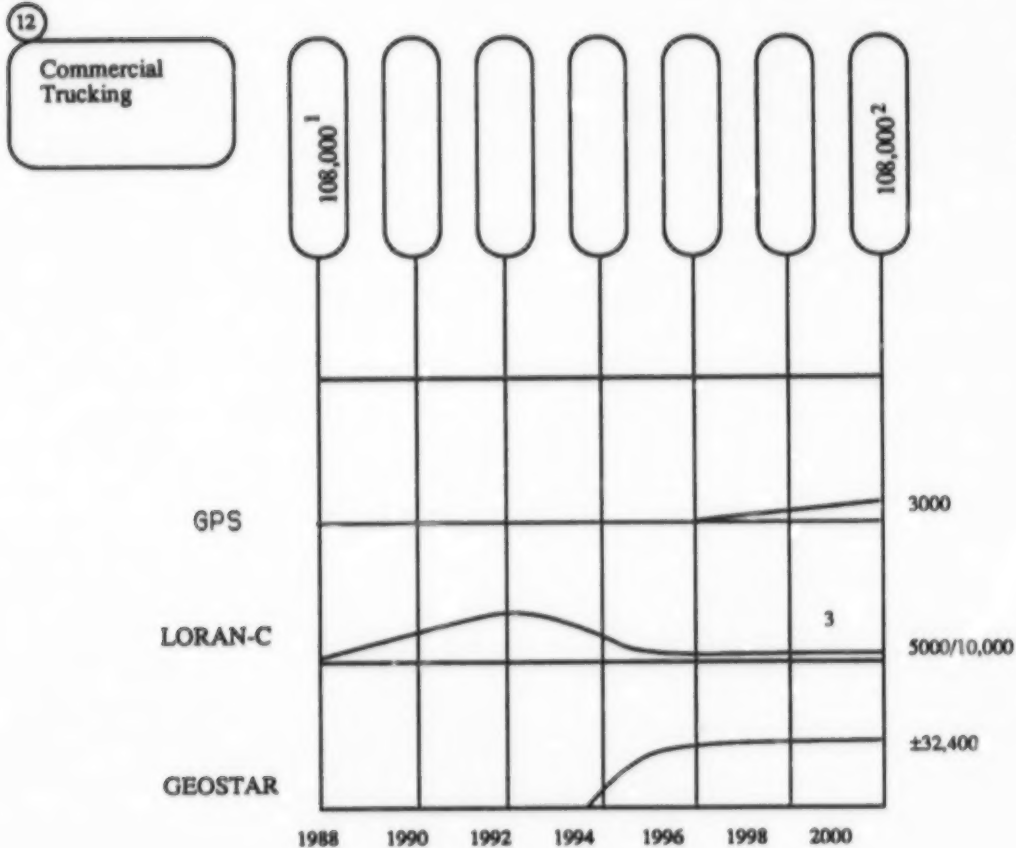
At present, two trucking companies are experimenting with a GEOSTAR based system (temporarily using LORAN-C for location and tracking). Early results appear to indicate that these devices are cost effective and it is expected that their use will spread rapidly among class I carriers. Given the needs of commercial truckers which are primarily location for monitoring and en-route dispatching, the favoured system is clearly the Active Satellite Systems. (It is, however, possible to use a LORAN-C with a communication satellite such as MSAT.)

On the basis of the close match between Active Satellite Systems and commercial trucker needs, and given the already apparent economic advantages of Active Satellite Systems, it is expected that the GEOSTAR radionavigation system will make a strong penetration in the trucking market. Even without considering the possibility of adoption by Level II and Level III operators, (some of which may be forced into it by contract with large clients such as Canada Post), it is realistic to expect that up to 30 per cent of commercial trucks (30 per cent of Level I) will be equipped with an Active Satellite System by the year 2000. If anything, this forecast could be conservative if dangerous (and potentially polluting) goods carriers are forced to install such devices.

It is expected that the LORAN-C will lose its current dominance in this market when GEOSTAR becomes fully operational, but it will retain a market share in local P&D operations for which it is better adapted than GEOSTAR. A small number of vehicles (5% range) may also use the GPS option.

FIGURE 20B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



- 1 Based on Statistics Canada Class 1 1985 Carriers Statistics
- 2 Based on 1985 statistics, assuming no substantial change
- 3 Local P&D market.

FIGURE 20C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4	X	1-2
3		
2	X	1-2-3
1	X	

4.1.24 Department of National Defense (DND), Radionavigation Requirements

Introduction

DND operates "soft skinned" vehicles such as jeeps, trucks and cars as well as "hard skinned" vehicles such as tanks and personnel armoured carriers. Besides these DND also operates long range foot and mechanized patrols for which it requires man pack navigation systems. All of them operate "on" as well as "off road", in urban as well as remote areas. DND requirements are summarized in Figure 21A.

Requirements

DND has two basic requirements for surface navigation. The first relates to navigation in the high arctic, where magnetic conditions make traditional methods unreliable; the second relates to navigation in other areas. By other areas DND literally means the rest of the globe.

A "Statement of Requirements, Preliminary" outlining DND's navigation requirements is being prepared. At present, no systems have been selected, parts of the plan are still undefined and others are classified.

In the Arctic, the Primary Land Arctic Navigation System (PLANS) is being developed to study DND's land requirements. The system combines Transit, GPS, Omega, Magnetic and Gyro compasses and odometers. The accuracy is on the order of 200 metres. The cost of the integrated system is likely to be too high for wide civilian use ($\pm \$150,000$ per unit).

It is expected that the system eventually selected will offer three major functions: Positioning, tracking and navigation; DND also has a requirement for precise orientation for artillery and other purposes. The probable update rate requirement would be in the one minute range, availability would have to be continuous, even under adverse hostile conditions. The required accuracy is considered classified.

Present System/Benefits Expected or Desired

Not applicable.

Current and Future Location/Navigation Options and Barriers

Information regarding systems currently in use by DND is classified for reasons of security. As DND requires an arctic and world-wide coverage, the appropriate technologies would probably be based on a satellite system such as GPS, or on a RDSS coupled with satellites.

FIGURE 21A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

MILITARY

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAIL. ABILITY HRS/DAY (1)	RELI- ABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. DND	Cars Trucks Off road Portable	Road Off road Portable	N/AV	< 200 m	Worldwide	24	N/AV	< 1 min.	N/AV	Better navigation in the arctic and other areas.	7776

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

4.1.25 Department of National Defence (DND), Present and Future Size of the Relevant Fleet

DND operates "soft skinned" vehicles such as jeeps, trucks and cars as well as "hard skinned" vehicles such as tanks and personnel armoured carriers. Besides these, DND also operates long range foot and mechanized patrols for which it requires man pack navigation systems. All of them operate "on" as well as "off road", in urban as well as remote areas. Information on the present size of DND's fleet is as follows.

1/4 ton jeeps	2485
2 1/2 ton jeeps	2762
Tanks	128
Northern Terrain Vehicles	820
APC	1090
AUGI	<u>491</u>
Total	7779

Needs and Match (See Figure 21C)

DND has two basic requirements for surface navigation. The first relates to navigation in the high arctic, where magnetic conditions make traditional methods unreliable; the second relates to navigation in other areas. By other areas, DND literally means the rest of the globe.

In the Arctic, the Primary Land Arctic Navigation System (PLANS) is being developed to fulfill DND's study land requirements. The system combines Transit, GPS, Omega, Magnetic and Gyro compasses and odometers. The accuracy is in the order of 200 metres. The cost of the integrated system is likely to be too high for wide civilian use ($\approx$ \$150,000 per unit).

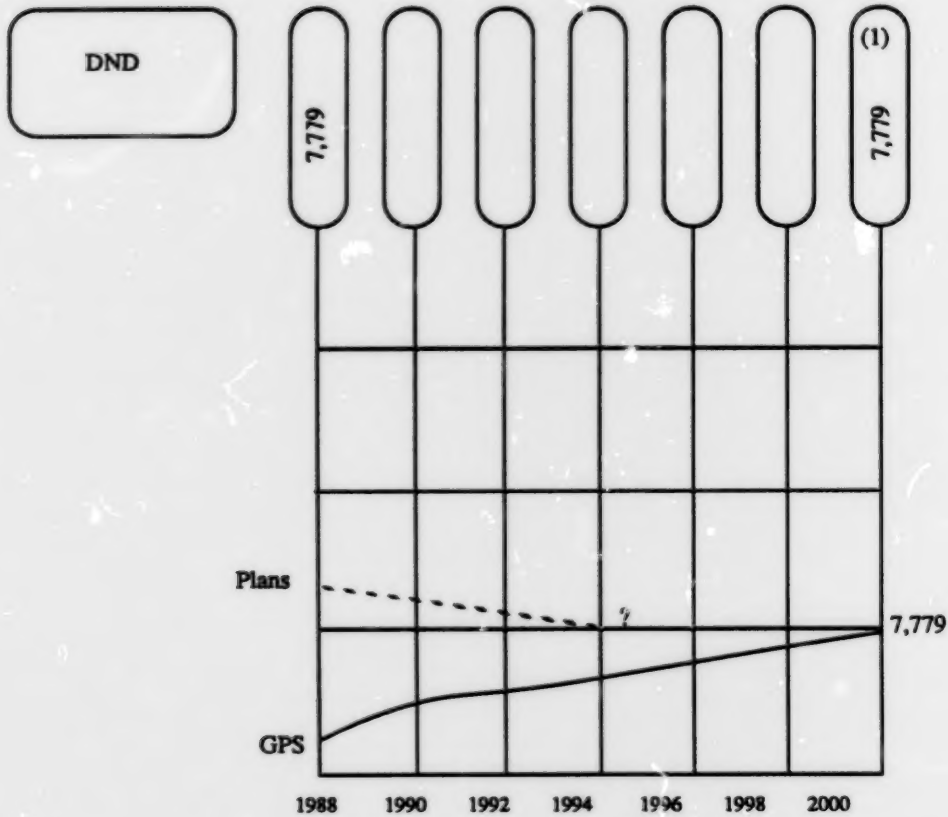
It is expected that the system eventually selected will offer three major functions: Positioning, tracking and navigation; DND also has a requirement for precise orientation for artillery and other purposes.

Type and Extent of Present and Future Use (See Figure 21B)

Given the requirements for worldwide availability and operations under adverse hostile conditions, only the GPS and GPS derivatives such as PLANS can be considered. Although timing and quantities are classified, it is possible to forecast with confidence that by the year 2000 all ground surface radionavigation needs of DND will be GPS based.

FIGURE 21B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



1. No available projections, 1988 figure used.

FIGURE 21C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5	X	2
4	X	2
3		
2	X	2
1		

4.1.26 Private Use, Radionavigation Requirements

Introduction

The private use typification regroups all types of vehicles intended for private use, whether privately owned or rented. It therefore includes:

- o Passenger vehicles;
- o Recreational vehicles (self powered);
- o Rental cars;
- o Vans and small truck rentals; and
- o Off road portable/personal orienteering.

The private use typification is based on the assumption that it is the requirements of the user rather than the characteristics of the vehicle which dictate the desirable parameters of the system. It is recognized however that in the case of rented vehicles, be they cars, vans, recreational vehicle or even trailers, the rental company has additional needs above and beyond those of the user. These have been discussed when appropriate.

Private use vehicles are basically employed in two distinct environments:

- o routine travel, and
- o non-routine travel.

Routine travel includes those repetitive activities which occur in proximity to the driver's residence or place of work. Non-routine travel is best described as tourism related. In North America, tourism related travel may range over very large areas and may encompass dense urban sections as well as uninhabited remote areas. As a rule, most location /navigation requirements are related to the non routine travel, although it is recognized that there may be a need for location, route guidance and communication in (minor or major) emergency situations even in routine travel situations.

The information pertaining to passenger vehicles has been obtained primarily from the literature review and from interviews with CAA Tourism and Conventions officers. Information on car and trailer rentals was obtained from vehicle rental companies. Personal/portable use information came from the Canadian Orienteering Society. Figure 22A summarizes the information obtained from the sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Private Use sector.

Requirements

When in a non-routine travel status, private use vehicles would benefit from a location/navigation /route guidance set of functions, as long as they are available on a map matching or other user friendly display device. One should not expect private users to interface with a system which provides information in latitudes and longitudes, nor can the private user be expected to possess the expertise to deal with problems of signal ambiguity or similar types of complexities.

FIGURE 22A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

PRIVATE USE

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Car Rental	Cars	Road	Guidance Navigation Dispatching	15-65	Continental	24	N/A/V	<1	N/A/V	Silent witness To aid in fleet management	20,000
2. Truck/Trailer Rental	Trucks Trailers	Road	Positioning Monitoring Guidance Navigation Dispatching	65-200	Continental	24	N/A/V	60+	Telephones	To Assist Clients in Navigating And For Marketing Purposes	9,000
3. Private Touring	Cars & RVs	Road Rail	Positioning Tracking Guidance Dispatching	6-15	Regional	24	N/A/V	N/A/V	N/A/V	On board database on tourist information	N/A/V
4. Orienteering	back pack	Portable	Tracking	6-15	Local	24	N/A/V	N/A/V	Compass & Map	Search and rescue Map making	N/A/p
SUMMARY: Private Use	Cars Trucks Trailers RVs	Road Rail	Positioning Monitoring Guidance Tracking Navigation Dispatching	6-15	Continental	24	N/A/V	<1	N/A/p	N/A/p	N/A/p

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent

Besides navigation and route guidance information, users would benefit from being able to access information on hotels, eating places, gas stations, mechanics, and events and attractions. Because the user is likely to be a tourist, tourism related information such as most scenic rather than most efficient route should also be available. Information on present position (for future reference), as well as on sights and landmarks visible from the vehicle would probably also be appreciated. In the case of RV's, this requirement extends to non urban and even remote areas.

Car rental companies consider that their clients would appreciate having access to route guidance and navigation. When these services become available (technically and economically), major car rental companies will most likely offer them, either as an additional option (as is occurring with cellular phones) or as a marketing promotion. When they do, they will start with the cars being rented in large urban areas. For Company 1 this represents a potential market of 17,000 vehicles (85 per cent of the fleet of 20,000 vehicles). Overall, the potential car rental market is between 100,000 and 120,000 vehicles for the five major Canadian car rental companies.

The companies themselves might be interested in a vehicle location or tracking capability for the purpose of tracing missing vehicles but they feel that their clients may not appreciate the resulting invasion of privacy.

Car renters tend to keep their vehicles for a maximum of six months, as such they require on-board systems which can be easily installed and removed without damaging the resale value of the vehicle. Portable units are not necessarily a solution as car renters require an on-board unit which is not prone to be stolen. Because of the preceding, car rentals might favour GEOSTAR satellite type system because the interrogation feature makes stolen units unusable (cellular phones have the same advantage). On the other hand, their "where are you" feature is not very useful to the user.

Company 2 is by far the largest Canadian one-way van, truck and trailer rental company in Canada. The Canadian fleet includes 5,000 trucks and 4,000 trailers. Company 2 would use a once a day location device if it was cost effective in tracing late (including lost and stolen) units. It does not believe that there is a need for actually tracking its vehicle. As is being done in many other fleets, one-way trucks would benefit from a monitoring unit capable of keeping track of gas consumption, oil and tire pressure, etc. There is no requirement for the information to be communicated in real time, it suffices that it be benchmarked at the beginning and available at the end of each trip. Company 2 does not require a dispatching function, all vehicle transfers are arranged over the phone. If a customer has a problem, the company can be contacted via an 800 line. Because one-way truck renters generally plan their trip carefully, no navigation function is required. The route guidance function could be attractive to users when they have to cross urban areas, but it would have to be available in a cost effective plug in unit because the proportion of users would be small.

The Canadian Orienteering Association does not purport to represent all the potential users of portable personal location navigation devices, these devices are in fact more likely to be used by hunters, fishermen, prospectors and cross country skiers than by orienteering aficionados which are prevented by the rules of their sport to use anything beyond a map and compass. On the other hand, professional orienteering map makers are familiar with the requirements for such equipment and would use it if available. Location beepers are already being used in Sweden to track the progress of competitors in international orienteering events.

Present Systems

The only vehicle location/navigation systems currently available in Canada are the LORAN-C and GEOSTAR (but is not used for that purpose).

Benefits Expected or Desired

The main benefits expected from the availability of the location/navigation/route guidance functions is in terms of more pertinent timely information. If the navigation and route guidance information are available on a display device compatible with the safety requirements of the driving function (for example, voice or head up display), it may substitute the presently used maps and CAA triptychs.

Vehicles will be easier to find in emergency situations. For that matter vehicles may be harder to steal.

The route guidance is the function which appears to hold the greatest promise of benefits for continuous use in routine travel. Timely traffic information, coupled with an appropriate expert software would give commuters a real opportunity to select alternate routes on an on-going basis.

Current and Future Location/Navigation Options and Barriers

There are a great variety of systems being developed for use by private vehicles all over the world, the major ones are described in Section 6: Navigation Systems description.

4.1.27 Private Use, Present and Future Size of Relevant Fleet

The private use group encompasses all vehicles intended for private use whether privately owned or rented, including cars and light vans. The major components are:

		<u>Source</u>
Recreational passenger vehicles	11,139,183	(Canada Census 1986)
Car rentals	110,000	(Industry estimates)
Vans and small trucks (rentals)	<u>9,000</u>	
Total	11,258,183	

According to estimates (from industry sources) the growth in this overall group is expected to be in the five per cent range by the year 2000.

Needs and Match (See Figure 22C)

The primary focus of the private user is navigation. This includes Level 1 monitoring off-line for maintenance, with no location input required, capabilities at the Levels 2 (self positioning) / (automated route selection and optimized route selection) and Level 5 (automated navigation). At this point, it cannot be said that there is a real demand for Level 6 (automated guidance).

For normal day-to-day use it is expected that the greatest benefit could be the availability of an optimized route selection (4+) capability to be used for commuting purposes (best route according to traffic). For tourists and when in unfamiliar areas, private users will certainly appreciate the added convenience of the Level 5 automated navigation from point A (given by the Level 2 capability) to point B even if there is no optimization

function.

The fact that the private users group can benefit from services ranging from Level 1 (off-line monitoring for maintenance) as well as from Levels 2, 4 and 5 seems to indicate that once a viable and affordable system becomes available, demand should grow very rapidly. It must be noted that private users will require a user friendly system capable of giving information by voice, on a head-up display or at the very least, on a digitized scrolling map.

Type and Extent of Present and Future Use (See Figure 22B)

The private sector is expected to be the area of greatest diversity with a number of on-board Dead Reckoning (with and without automated proximity device "fixes") systems competing with single and complex radionavigation systems. The extent of this competition and the fact that tourists may rent rather than buy radionavigation systems (as is happening with cellular phones for travelling business people) makes 12-year projections very difficult. The best estimate which can be made at this point is that in the next few years, private users should begin to use LORAN-C (as soon as the interfacing is made easier). Later in the decade, it is expected that the GPS system will become cost competitive (at the higher price end) and should capture a considerable market share.

Given the attractiveness of navigation systems to the private users and the fact that these devices are expected to become available as additional original equipment in most vehicles by the end of the 1990s, it is expected that navigation systems of all kinds may capture as much as 50 per cent of the entire market with radionavigations getting as much as 25 per cent of the total.

Although no firm forecasts exist, the best estimate is that LORAN-C would hold (a declining) 7 to 10 per cent market share while Passive Satellite Systems would command a 10 to 15 per cent (and fast growing) market share (by the very end of the century).

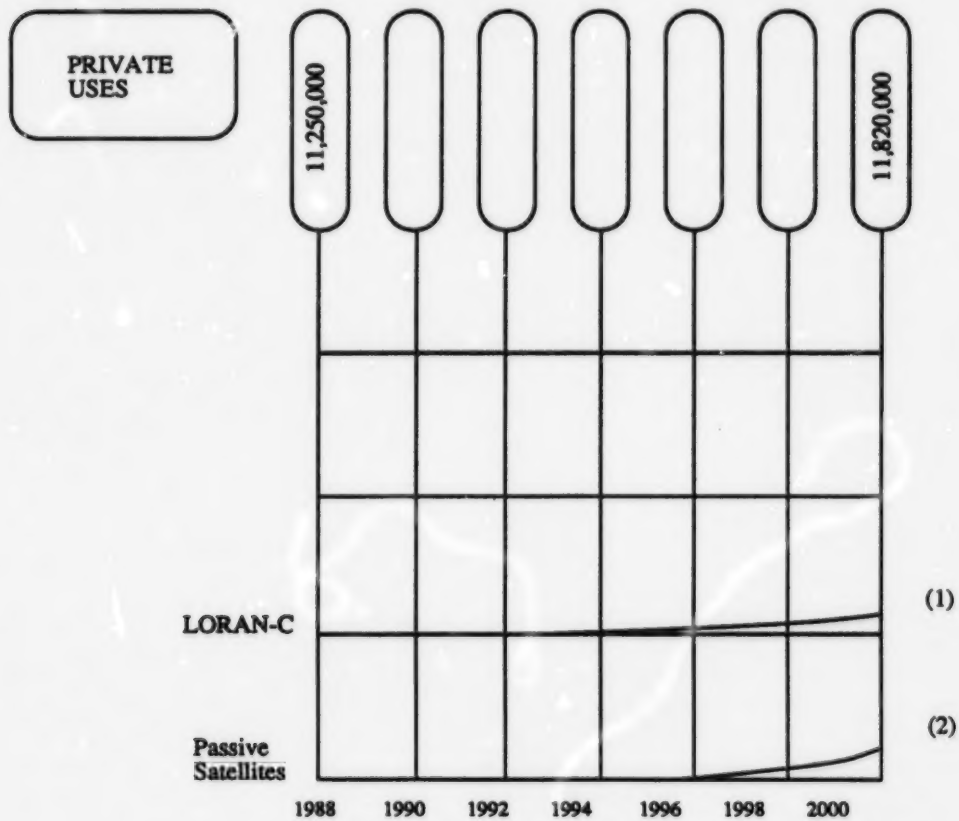
The unknown is represented by Active Satellite Systems. They have the best theoretical potential to offer optimized routing but this would require that a considerable proportion of users subscribe to the service (and a much faster update rate) which is unlikely ('where-are-you' is not relevant for private users).

If roadside or road bed sensors become available to feed traffic information through a communication adjunct to Passive Satellite Systems (or LORAN-C) this could increase demand very rapidly, but it is not expected in Canada before the year 2000.

A 50 per cent market penetration in 12 years may appear over optimistic (and it may turn to be so), but this forecast is based on the fact that the Japanese have already introduced (a non-radio based) navigation system in one of their latest cars with surprising results (25 per cent of the cars of that particular model are being sold with the system).

Furthermore, a number of American and foreign car manufacturers have already expressed their intention to introduce navigation systems in the next few years. Also a number of European countries are investing \$800M (U.S.) on the PROMETHEUS project (Intelligent Highway/Vehicle Program). All of the above, coupled with the success of cellular phones, indicates that car buyers and drivers are willing to pay thousands of dollars for real, added convenience thus making a 50 per cent penetration for all systems less unrealistic.

FIGURE 22B
TYPE AND EXTENT OF PRESENT AND FUTURE USE



(1) equivalent to approximately 830,000 to 1,200,000 vehicles
 (2) equivalent to approximately 1,200,000 to 1,800,000 vehicles

FIGURE 22C
NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5	X	2 - 3
4	X	2 - 3
3		
2	X	2 - 3
1	X	

4.1.28 Agriculture, Radionavigation Requirements

Description

The Agricultural group is mainly focussed on the needs associated with prairie farming, especially custom operators and big farmers. It also addresses, but to a lesser degree, the needs of cattle and other ranchers. Other agricultural needs of fruit growers and small farmers are not specifically covered.

In years past, fertilizer recommendations were made on a province wide basis. Later-on they were made per zone and then on a field by field basis. The current thinking is that even within a single field, application rates should vary from area to area. The same reasoning is being applied to seeding, herbicide and insecticide spraying.

With the availability of a precision radionavigation system this approach could be implemented through the following steps: Starting from a digitized aerial photo of a given field an analysis (of the grey scale) is undertaken to assess nitrogen and potassium deficiencies. The information is then supplied to an on-board computer connected to a precise radiolocation/navigation device. The appropriate implement can then be made to automatically match applications to requirements.

Early adopters are likely to be custom operators. These are local rural businesses which do contract custom agricultural work. Custom operators tend to use large modern equipment. Custom operators have an incentive to adopt precise radiolocation spraying because the fee they charge for their services is not affected by the amount of product utilized. Large farmers who use up to \$50,000 a year in fertilizers alone are expected to welcome a technology which promises substantial reduction in amounts used.

For ranching purposes, radiolocation equipment could be used to track cattle, it could also conceivably be used as some form of "electronic fence".

In order to develop the Agricultural typification, interviews have been conducted with officials of two corporations which are in the process of developing radionavigation equipped farm tractors. Figure 23A summarizes the information obtained from the two sources. The paragraphs that follow present a more detailed description of the information supplied by the interviews and a typification of the requirements of the Agricultural sector.

Requirements

To insure full coverage while avoiding gaps and overlaps, the key requirement is for high accuracy navigation. The minimum accuracy required is between 1 and 10 metres (which is equivalent to the width of modern farm machines). Tracking is not an important requirement in the agricultural sector but may represent an important requirement for ranching.

Monitoring does not appear to be an important requirement.

FIGURE 23A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

AGRICULTURE

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Agriculture	Farm equipment & Tractors	Off road	Navigation Dispatching Tracking	minimum 1-10 metres desired > 10 Cm	Rural	12/24	N/Av	>1 (continuous)	Private RF networks	To keep farm equipment on course To optimize spraying etc...	N/Av
2. Agriculture & cattle	Farm equipment & Tractors & Cattle	Off Road	Navigation Dispatching Tracking	N/Av	Rural	24	N/Av	> 1	none	Electronic fencing	N/Av
SUMMARY: Agriculture	Farm equipment & Tractors & Cattle	Off road	Navigation Dispatching Tracking	minimum 1-10 metres desired > 10 Cm	Rural	24	N/Av	>1 (continuous)	N/Av	N/Av	N/Av

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

Dispatching may be of interest to large custom operators who operate in unfamiliar surroundings.

Availability requirements would be mostly for daylight hours (although some U.S. custom operators work three shifts).

Coverage must be broad enough to encompass a 1 mile range (ideally 6 miles) if the system is to be based on a private RF system.

To eventually allow for automated guidance the system should be able to supply precise information on heading, and position (within 10 centimeters).

Present System

The most modern current systems operate on a feed-back loop basis. Soil samples are taken at the front end of the fertilizer spreader, an automated summary analysis is performed and the results are used to calibrate the amount of fertilizer being pulverized. The analytical capabilities are however restricted to a few basic elements. The above system cannot be used for pest control.

Benefits Expected or Desired

Computer assisted decisions capability with respect to direction, speed, turning points and intensity of spraying is the primary benefit expected from the use of radionavigation systems. At a later date it is expected that some farm equipment may be computer guided.

With respect to ranching, the prospect of electronic fencing is considered as having considerable labour and equipment saving implications.

Current and Future Location/Navigation Options and Barriers

Farming requires accuracies which are well beyond what is currently available or planned, save for some high cost private RF systems (\$80,000 and over). The LORAN-C network even with a differential station, is not capable of such levels of accuracies. The GEOSTAR system would not be appropriate because its primary focus is tracking and dispatching rather than (high precision) navigation. The time delay in signal transmission almost rules out GEOSTAR as a guidance system. The GPS system, in a differential mode, could offer accuracies in the 1 to 5 metres range and with the potential to eventually reach the 10 cm range.

Cost of equipment would be less of a barrier in the agricultural sector than in others because the radionavigation system would be a comparatively small option on a full fledged modern tractor (or air seeder). For example, it is estimated that an automated system costing in the \$10,000 to \$15,000 range would be an attractive option on many (up to 1/3) of the 20,000 air seeders operating in Canada. This number is expected to grow by 5,000 to 6,000 a year until it reaches some 70,000 units in or about 1995.

4.1.29 Agriculture, Present and Future Size of the Relevant Fleet

As indicated in the Part I study, pages 56 and 57), the most likely agricultural users are the custom operators and the big grain farmers.

We have not been able to obtain an estimate for the number of custom operators in Canada, but Statistics Canada indicates that there were approximately 90,000 farms in

Manitoba and Saskatchewan, with the average size of the 700 acres for Manitoba and 1,000 for Saskatchewan by using the standard 80/20 it would appear that one could put the number of large farms at somewhat in the vicinity of 20,000.

It is probable that the overall number of Prairie farms will decrease from now until the year 2000. On the other hand, the decrease should be mostly concentrated with small farm groups and the number of large farms should remain stable (but their acreage could continue to grow).

Needs and Match (See Figure 23B)

Farmers have several levels of needs. For spraying and fertilizing on the basis of aerophotography (see the Part I Study), they need a Level 2 (self positioning). For automated navigation (Level 5) to be of use, accuracy must be in the one to 10 meters range. For automated guidance (command tractors) accuracy should be in the one to 10 cm range.

As can be seen, farmer requirements are stringent. On the other hand, benefits are very considerable and farmers may be willing to invest in small differential transmitters aimed at giving them the desired accuracy.

Given the cost of a modern tractor, the addition of a radionavigation system should not represent a significant barrier to purchase. On the other hand, savings in terms of chemicals and in terms of gained efficiency would be a major incentive to purchase once operational systems are available.

Type and Extent of Present and Future Use (See Figure 23A)

There are no navigation devices in use by farmers at this time, but several systems are being developed. It is expected that with the help of low power FM differential stations, it will be possible for farmers to achieve the one to 10 meter accuracy range, if not the ultimate centimetre range (which would allow round-the-clock driverless farming).

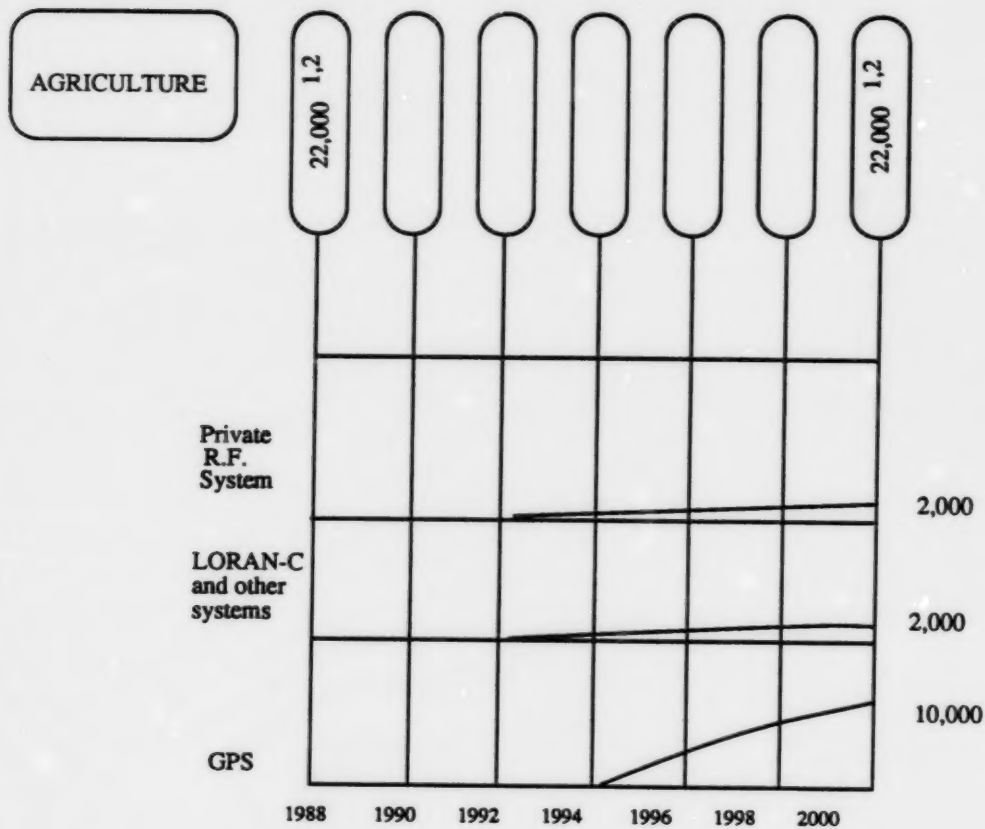
With these benefits, it is expected that as many as 50 per cent of large farms will be equipped by the year 2000 (10,000). This number probably underestimates the total market because it assumes only one large tractor per farm and ignores custom operators. Assuming 2000 tractors for custom operators (servicing the smaller farms); the number could be as much as 12,000.

It is expected that a majority (up to 8,000) of the farmers will opt for the GPS system (although it will have to be coupled with a local temporary differential station) with the remainder using either LORAN-C (2,000) or private radio frequency based systems (2,000).

The above are preliminary estimates. Figures will tend to evolve when technologies mature.

FIGURE 23B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



- 1 Includes Saskatchewan and Manitoba only; the number of large farms has been estimated at 20% of the total number of grain farms in these provinces.
- 2 Includes 2000 tractors (estimate) operated by "custom operators".

FIGURE 23C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6	X	2
5	X	2 - 3
4		
3		
2	X	2 - 3
1		

4.1.30 Fishing, Hunting/Search & Rescue, Radionavigation Requirements

Fishing, hunting and land search & rescue requirements are being presented together because it appears that fishermen and hunters (as well as outfitters and organizers of remote expeditions) consider that their primary requirement is for emergency location aimed at facilitating search & rescue. The navigation requirement, when it exists is considered secondary.

The fishing, hunting, search & rescue typification was based on interviews conducted with the National Search and Rescue secretariat and with the senior editor of the outdoor Canada publishing company. Figure 24A is a summary of the requirements for this sector, details are discussed below.

Requirements

Fishermen, hunters (especially those operating in the north), trappers, hikers and people going on expeditions share three basic requirements. The first is to be easily (and quickly) located in case of emergencies, the second is to navigate from point A to B and the third is to maintain (at least intermittently) a communication link with their base.

Emergency location is presently being satisfied by ELT and EPIRB transmitters (details below), but back pack use by individuals is still rare due to cost and to some extent due to weight. Available emergency location transmitters work on the following principle: when an emergency occurs, the transmitter is triggered (manually or automatically) and it begins sending a signal which is picked up by the SARSAT or COSPAS satellite and retransmitted to the search & rescue authorities. The satellite uses the Doppler effect to locate the origin of the emergency beacon.

Tracking, monitoring, route guidance and dispatching do not appear to be primary considerations.

Navigation does not appear to be a major consideration in most cases. Fishermen are more or less restricted to a given lake, hunters tend to be accompanied by outfitters who know the territory well. Expeditions to the far north are a special case, they tend to rely on the Omega system and are expected to shift to the GPS when it becomes available.

Communication requirements are being satisfied by short wave, although the extension of the cellular system offers intriguing possibilities for "near urban" use.

Present System

The major systems presently in use are:

- SARSAT/COSPAS. These are polar orbiting satellites (COSPAS is the Soviet system), they allow the location of power transmitters by Doppler. One of their major drawbacks is that it may require more than one pass to locate a specific distress beacon.

FIGURE 24A

SURFACE LOCATION/NAVIGATION REQUIREMENTS

FISHING, HUNTING, SEARCH & RESCUE

APPLICATIONS	TYPE OF VEHICLES	TYPE OF USE	FUNCTIONS (1)	ACCURACY IN METRES (1)	COVERAGE (1)	AVAILABILITY HRS/DAY (1)	RELIABILITY (1)	UPDATE RATE IN MINUTES	CURRENTLY USED TECHNOLOGY	PURPOSE AND EXPECTED BENEFITS	NO. OF VEHICLES (2)
1. Search & Rescue	Portable	Off road	Location	65 - 200	Continental	24	N/Av	30 - 60	SARSAT COSPAS ELT EPIRB	To expedite Search & Rescue operations	N/Ap
2. Fishing, hunting and outdoors	Portable	Off Road	Location	N/Av	Continental	24	N/Av	N/Av	N/Av	To expedite Search & Rescue operations	N/Ap
SUMMARY: Fishing, hunting Search & Rescue	Portable	Off road	Location	65 - 200	Continental	24	N/Av	30 - 60	SARSAT COSPAS ELT EPIRB	To expedite Search & Rescue operations	N/Ap

(1) refer to Section 3.2 for details

(2) number of vehicles operated by respondent.

- ELT (Emergency Locator Transmitter) operates in the 121.5 Megahertz band, it is legislated for use in aircraft. At present, the unit cost (for aircraft use) is in the \$20,000 range. A considerable proportion of the cost is accounted for by the crash resistance requirement of the unit. ELT's for land use could be produced for as little as \$500 if produced in large quantities.
- EPIRB operates in the 406 Megahertz band, it is primarily intended for use in boats. At present the cost per unit is in the \$2,000 to \$3,000 range, but a considerable proportion of the cost is accounted for by the "float free" aspect and other elements of the packaging.

Benefits Expected or Desired

Search & rescue authorities would like to extend the use of emergency locator beacons to land surface users. For example they would like to see National and Provincial Park hikers, campers and canoeists equipped the emergency locators. They foresee a situation in which Park wardens will require Park users to check-out (or rent) such a device as part of the registration process.

Current and Future Location/Navigation Options and Barriers

The outdoors market represents a potentially very large market for emergency locators. It is less obvious that it also represents a market for radionavigation/communication equipment. the most likely scenario is that as radionavigation devices become widely available (as well as portable, rugged and low cost) outdoors practitioners will tend to remove their equipment from the vehicle and carry it along.

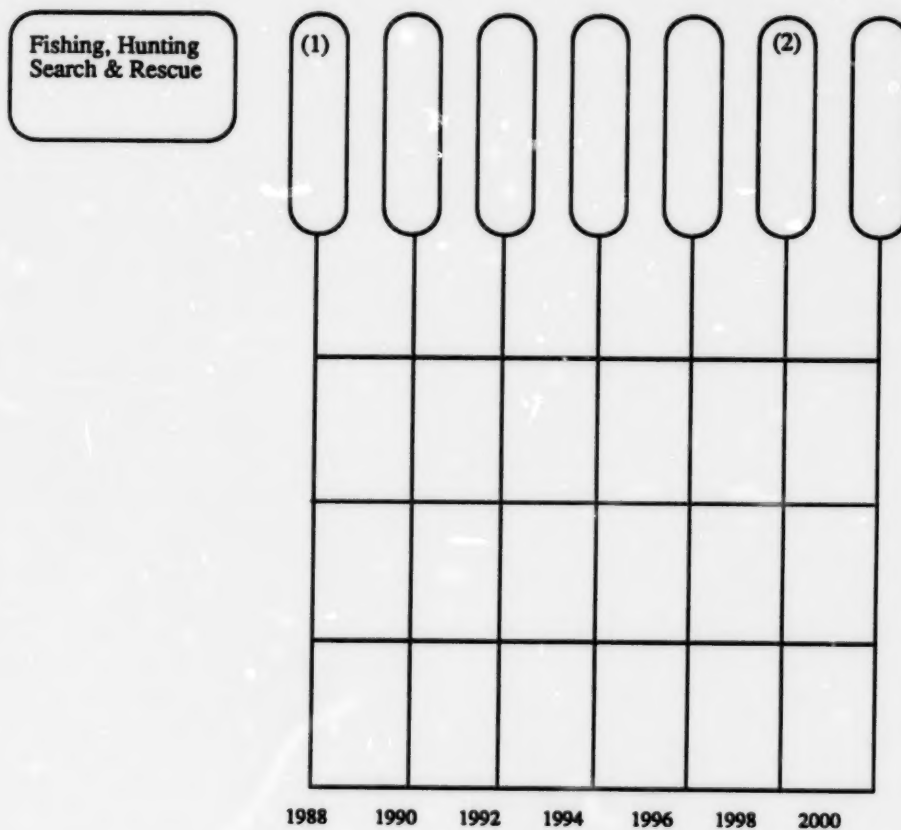
4.1.31 Fishing, Hunting/Search & Rescue, Present and Future Size of the Relevant User Group (See Figure 25 B and C)

No estimates of year 2000 use for this group was developed for the following reasons:

- o The focus of this study excludes radionavigation devices used on boats (of any size). Furthermore, it is likely to be a considerable overlap between boat equipment and car navigation systems;
- o It is not expected that a portable cost effective radionavigation receiver will be available in time to achieve a large civilian market before the year 2000;
- o Search and rescue operators are likely to use air-based equipment; and
- o Finally, it was considered impossible to define the type and number of hunters who might be potential users.

FIGURE 24B

TYPE AND EXTENT OF PRESENT AND FUTURE USE



1. Numbers not obtained.
2. No projections were made.

FIGURE 24C

NEEDS AND MATCH

LEVELS	NEEDS	MATCH
6		
5		
4		
3		
2		
1		

4.2 USER REQUIREMENTS/SYNTHESIS

In the preceding section, user requirements were presented for a variety of user groups. In this section the requirements are presented in such a way as to highlight the commonalities and differences between the requirements of various groups.

Specifically, user requirements have been grouped in a series of tables each of which focuses on one particular dimension. These are:

Functional Requirements:	This table summarizes the functional requirements of users and shows that although most users have expressed some level of requirement for most functions, the intensity of the requirement varies.
--------------------------	---

Accuracy Requirements:	This table summarizes accuracy requirements for the various groups.
------------------------	---

Coverage Requirements:	This table summarizes coverage requirements.
------------------------	--

Update Rate Requirements:	This table summarizes update requirements.
---------------------------	--

Note: In some cases, as in the case of private use, requirements may vary according to intended use (location, tracking, navigation, etc.). The information indicated in Figures 25.1 to 24.4 does not necessarily reflect the requirements for all intended users. For details the reader should consult the specific section.

FIGURE 25.1

SURFACE LOCATION/NAVIGATION REQUIREMENTS

ACCURACY/INTENSITIES

0-5 metres

Surveying (very high accuracy in the order of 1cm in 1 km or better)

Rail (must discriminate between adjacent tracks)

Agriculture (must avoid overlaps when plowing & sprayng).

6- 15 metres

Inter-city buses
Emergency vehicles
Comm. trucking
Rail (where on the track)
Private use

15-65 metres

Urban transit
Towing
Correctional services
Utilities

65- 200 metres

Taxi
Local Gov't
Search & Rescue

200+ metres

Canada Post

N/Available

Courier service
DND

Required

Desired

FIGURE 25.2

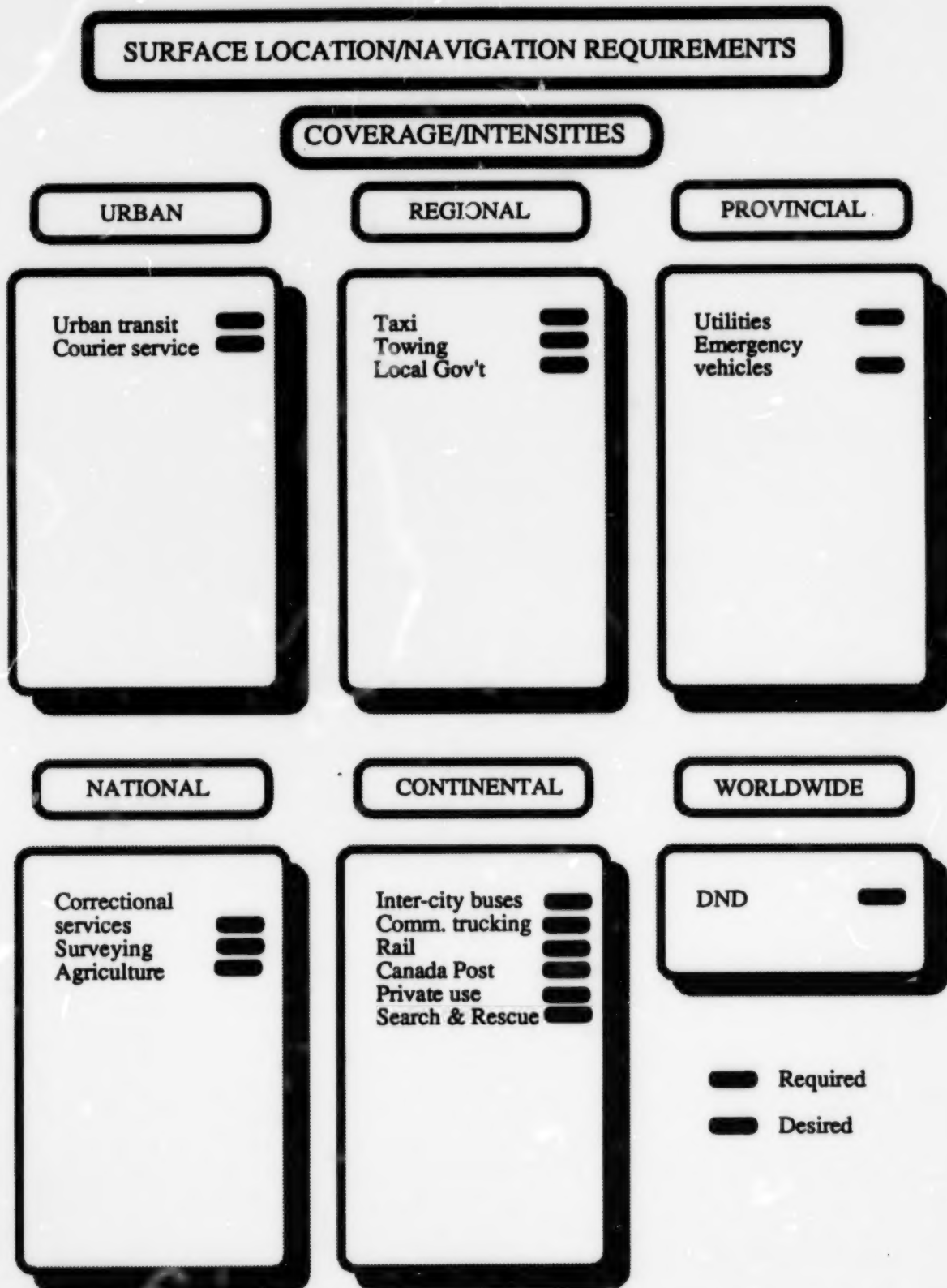


FIGURE 25.3

SURFACE LOCATION/NAVIGATION REQUIREMENTS

UPDATE RATE/INTENSITIES

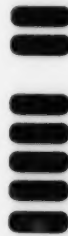
LESS THAN 1 MIN

Urban transit
Taxi
Emergency
vehicles
Towing
Private use
Agriculture



1- 15 MIN

Utilities
Local Gov't
Correctional
services
Courier service
Rail
Canada Post
Rail



16- 30 MIN

Comm. trucking
Surveying
Search & Rescue



DAILY

U-Haul



 Required
 Desired

FIGURE 25.4

SURFACE LOCATION/NAVIGATION REQUIREMENTS

FUNCTIONS/INTENSITIES

POSITIONING

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Utilities	☒
Emergency vehicles	☒
Towing	☒
Local Gov't	☒
Correctional services	☒
Comm. trucking	☒
Rail	☒
Canada Post	☒
Private use	☒
Surveying	☒
Agriculture	☒
Search&Rescue	☒

MONITORING

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Emergency vehicles	☒
Local Gov't	☒
Correctional services	☒
Courier service	☒
Comm. trucking	☒
Rail	☒
Private use	☒

TRACKING

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Emergency vehicles	☒
Towing	☒
Local Gov't	☒
Correctional services	☒
Courier service	☒
Comm. trucking	☒
Rail	☒
Canada Post	☒
Private use	☒
Agriculture	☒

GUIDANCE

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Utilities	☒
Emergency vehicles	☒
Towing	☒
Local Gov't	☒
Correctional services	☒
Courier service	☒
Comm. trucking	☒
Rail	☒
Canada Post	☒
Private use	☒
DND	☒

NAVIGATION

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Utilities	☒
Emergency vehicles	☒
Towing	☒
Comm. trucking	☒
Canada Post	☒
Private use	☒
Agriculture	☒
DND	☒

DISPATCHING

Urban transit	☒
Taxi	☒
Inter-city buses	☒
Utilities	☒
Emergency vehicles	☒
Towing	☒
Local Gov't	☒
Courier service	☒
Comm. trucking	☒
Rail	☒
Canada Post	☒
Private use	☒
Agriculture	☒

☒ Required

☐ Desired

5.0 SUMMARY OF FORECASTED DEMAND FOR THE THREE SCENARIOS

The forecasted demand for each radionavigation system for the year 2,000 as detailed in Section 4.0 of this report is summarized in the following tables.

Active Satellite Systems (GEOSTAR)

User Groups	Year 2000
Urban Transit	1,200
Intercity Buses	55
Canada Post	2,000
(Long Haul Contract Carriers)	
Correctional Services	4,000 to 6,000
Commercial Trucking	32,400
Total Active Satellite Systems	39,655 to 41,655

Passive Satellite Systems (GPS)

User Groups	Year 2000
Charter Buses	225
Utilities	6,000
Emergency Vehicles	2,000 to 4,000
Surveying	500 to 800
DND (approximately)	8,000
Courier Services	3,180
Commercial Trucking	2,500 to 5,000
Private Uses	830,000 to 1,200,000
Agriculture	10,000
Total Passive Satellite Systems	862,405 to 1,334,025

Ground Based Systems (LORAN-C)

User Groups	Year 2000
Emergency Vehicles	5,000 to 10,000
Courier Services	2,120
Commercial Trucking	5,000 to 10,000
Private Users	1,200,000 to 1,800,000
Agriculture	2,000
Total Ground Based Systems	1,214,120 to 1,824,120

Other (Dead Reckoning, Proximity Devices)

User Groups	Year 2,000
Urban Transit	5,900
Total Other	5,900

6.0 NAVIGATION SYSTEM DESCRIPTIONS

6.1 INTRODUCTION

Navigation systems typically consist of a group of input sensors which provide position, location, direction, velocity and/or acceleration data to a display which may or may not be computer controlled. The output data is usually displayed in a format best suited to assist the navigator.

A radionavigation system includes the facilities, the operational requirements, the level of service, as well as the plans, policies, rules and standards for the provision and maintenance of the facilities. Radionavigation systems recognize that communications and other non-radionavigation systems do exist, and that appropriate interfaces may be necessary. The focus of this review is however on the radionavigation aspects, not on the communication or other characteristics of a given system.

For purposes of description, navigation systems have been grouped as follows:

- 6.2 **PRESENT NON RADIO NAVIGATION SYSTEMS**
- 6.3 **PRESENT SURFACE BASED RADIONAVIGATION SYSTEMS**
- 6.4 **PRESENT SATELLITE BASED RADIONAVIGATION SYSTEMS**
- 6.5 **FUTURE SYSTEMS**

6.2 PRESENT NONRADIONAVIGATION SYSTEMS

Non radionavigation systems are generally based on a combination of dead reckoning, map matching and simple or differential odometers. Magnetic compass is only mentioned as a reference, no modern system is actually based on its use.

6.2.1 Dead Reckoning

Dead Reckoning (DR) is a system which assumes that the starting position is known. Then by keeping track of direction and speed and by using a frame of reference or a map it is possible to estimate new positions by integrating the velocity vector (direction and speed) with respect to time. Nearly 90 per cent of all actual navigation is accomplished using some form of aided DR system. However, the overall inaccuracy of DR systems on land is about one to three per cent. All DR systems have errors which increase with time and, therefore, must be periodically updated.

The expected surface users for this system include:

- o **public services** (i.e., urban transit vehicles, passenger rail - regional and intercity)
- o **goods movement** (i.e., freight trains)

6.2.1.1 VDO (City Pilot)

City Pilot, a land navigation system which is based on dead reckoning, is available on the European market. It was developed by VDO Adolf Schindling AG and utilizes a magnetic compass and an odometer distance sensor. Navigation is based on the vehicle's

coordinates relative to an initial location. The system has an accuracy rate of 97 per cent.*

6.2.1.2 Etak Navigator

Etak Navigator is another land navigation system which was the first commercially available navigation system based on DR and uses a process called "map matching". Map matching applies artificial-intelligence pattern recognition concepts to correlate measured vehicle paths with road maps which are digitized and stored in computer memory. The system includes a monochrome CRT which displays maps in various scales.

6.2.1.3 EVA

Bosch-Blaupunkt developed a map-matching system called "EVA", "which uses a differential odometer and includes route-search software to generate an optimum route to input destinations. Synthesized voice capability is included, and is used to confirm destination entries as well as to articulate turn-by-turn, real-time route guidance instructions". The purpose of the synthesized voice capability is to enable the driver to concentrate on the driving rather than on the monitor.

6.2.1.4 CARIN

A system developed by CARIN adapted the system EVA "to receive real-time traffic information over a suitable data communication link, and to take this information into account in providing guidance over routes optimised for minimal travel time under the prevailing traffic conditions".*

6.2.2 Magnetic Compass

The magnetic compass has been used for about 900 years. Its properties and necessary corrections are well understood. Magnetic variations (caused by the changing location of the magnetic north pole) and magnetic deviations (caused by the changing magnetic effects of the vehicle) limit the accuracy of a corrected compass to plus or minus two degrees depending on the type of compass and the vehicle used. The magnetic compass is also subject to dynamic errors caused by linear and rotational accelerations. The pure magnetic compass is only used in the simplest form of navigation and then usually only as an emergency device for determining heading.

6.2.3 Inertial Navigation System (INS)

An INS consists of accelerometers and gyroscopes. The INS, because of its high angular momentum, has the property of being rigid with respect to the universe or to inertial space. To use this instrument on earth, compensation must be made for the rotation of the earth and the movement of the gyro as it travels around the earth. The simplest gyroscope is the directional one. However, this instrument tends to drift and, therefore, must be periodically reset from other reference systems.

* Robert L. French, "The Evolving Roles of Vehicular Navigation", R.L. French and Associates, Fort Worth, Texas, June 1987.

The Position and Azimuth Determining System (PADS) can achieve accuracies to better than three feet after travelling 25 miles. These systems cost about \$300,000.

6.2.4 Gyro-Magnetic Compass

The compensated gyro-magnetic compass uses a stabilized magnetic sensor and a low drift gyro to achieve an accuracy of 0.75 degrees in the slaved mode with a two degree per hour drift. Any further improvements to the gyro-magnetic compass are unlikely because of limitations in knowledge of the earth's magnetic field. Gyro-magnetic compasses cost between \$2,000-12,000. However, on land, under zero velocity, gyrotheodolites are considered accurate to 0.001 degrees. Gyrotheodolites cost between \$12,000-40,000. Higher accuracies are attainable by making intermittent use of velocity checks and self-calibration of intermittent errors.

6.3 PRESENT SURFACE BASED RADIONAVIGATION SYSTEMS

There have been some 200 different types of radio positioning systems developed for use in determining position/location. All radio aids generate some form of a Line Of Position (LOP). Two intersecting LOPs define a location or position and three or more LOPs provide redundancy as a check on the reliability and allow statistical averaging. LOPs are generated either as bearings, ranges or hyperbolic lines.

Coverage of a radionavigation aid is dependent on the range at which a receiver can adequately receive and process the signals from the transmitter to determine the position or location. This ability to receive is dependent on the transmitter location, the signal strength, the terrain between the transmitter and the receiver, and the conditions of the propagation medium.

6.3.1 Doppler Radar

Doppler radars are being used in connection with air traffic because they can sense turbulence and wind motion and can thus depict the air mass motions which precede cloud formations and weather turbulences. The same qualities which make Doppler radars useful for weather tracking, i.e., the fact that waves are reflected differently by land, air, water, etc... tend to reduce its usefulness in typical land surface applications in very "cluttered" areas.

To date, very Small Gunn Diode doppler radars or laser velocimeters have been used as land navigation systems to eliminate odometer slippage and in conjunction with air cushion vehicles.

6.3.2 Non-Directional Beacons (NDB)

The frequency band 200-415 kHz. has been assigned to Marine Radionavigation while the 510-535 kHz. band has been assigned to Aeronautical Radionavigation. These frequencies are used almost exclusively for NDBs. The useful range of an NDB depends on power, ground conductivity and local noise. Ranges of up to 150 miles for 1 kw beacons are possible but it is common to have ranges between 20-30 miles. With two beacons separated by 150 miles the accuracy of the system can never be less than 25 miles at a 95 per cent confidence level. NDBs cost \$15,000-60,000 for 1-3 kw transmitters. Receivers cost between \$1,000-5,500. Two frequencies sent from different NDBs are necessary to determine a position. In general, NDBs do not provide accurate enroute navigation.

6.3.3 Omega

Eight 10-kilowatt stations are strategically positioned around the world to provide time signals at 10.2, 11.05, 11.33 and 13.6 kHz. The individual stations are slaved to Universal Time by cesium clocks. With all stations operating, any point in the world will receive signals from at least five stations, which ensures redundancy at all times there are problems with using Omega in the Arctic due to the low conductivity of the ice. Although Omega has a stated accuracy of one nautical mile by day and two nautical miles by night, actual static tests have shown accuracies between 1.6 and 4.4 nautical miles. Receivers cost between \$4,000-50,000.

Differential Omega is the comparison of the received Omega signal with the predicted signal at a fixed point and the transmission of a differential correction factor to the user. This correction factor can provide improved accuracies on the order of 0.3 to 1 nautical mile.

Differential Omega is the only current radionavigation system with established and published standards for the transmission of differential corrections. The only Differential Omega system developed to date is the one located along the French coast and in the Mediterranean where there are 15 stations in operation. That system was developed and is currently operated by French Government.

Differential Omega has been proposed as a northern radionavigation aid with one-quarter to one-half nautical mile accuracies within forty miles from a monitor station. However, this accuracy cannot be met under night time conditions.

6.3.4 Decca

Decca is a hyperbolic phase comparison system operating in the 70-90 kHz. as well as in the 110-130 kHz ranges. Decca uses a master control station as well as three phase locking slave stations to produce a usable range of about 240 nautical miles at night under normal atmospheric conditions. Accuracy is a function of geometry and has been quoted between 500 feet and three nautical miles. It can be calibrated to much better accuracy and has a high degree of repeatability. A four station Decca system costs nearly two million dollars with annual operating costs around \$200,000 per year. Receivers with moving map displays and interfaces to other system can cost up to \$140,000. Decca is no longer available in Canada but is used successfully in the North Sea.

6.3.5 LORAN-C

LORAN-C is a pulsed, hyperbolic system which operates in the 90-110 kHz. range. The system is based on measuring the time difference of pulse arrival using cesium clocks. Stations can be separated by hundreds of miles. One LORAN-C chain can cover the area of between 10-25 Decca chains. The effective range is dominated by transmitting power, ground conductivity, local noise and the method used to extract the signal information. Local noise may affect the system in dense urban and in industrial areas.

LORAN-C transmitter site costs vary widely depending on their power and location. Typical costs of a single station are about \$15 million. Receivers vary in cost from about \$1,000-50,000 depending on features and capabilities.

Differential LORAN-C system has been developed and tested by the U.S. Coast Guard for marine navigation in harbors and harbor approaches. The tests indicate that Differential LORAN-C is capable of meeting requirements in many, but not in all, harbors areas. The University of Ohio is conducting research in the area of Differential LORAN-C. The Research and Special Programs Administration of the U.S. Department of Transportation is also monitoring government and commercial activities for surface applications.

The expected surface users for LORAN-C includes: **public service** (i.e., urban transit vehicles, emergency vehicles - police and security, ambulance, fire); **goods movement** (i.e., courier vehicles, P&D trucks, intercity trucks & tractors, and other trucks & vehicles); and **military** (i.e., truck and portable/personal). There is also a potential market in personal/portable units.

6.3.6 Signposts (Proximity Devices)

The most common method used for location in transit systems is one whereby the location is determined by the relationship between the vehicle and fixed low-strength radio transmitters called signposts which are positioned along the route. As the vehicle nears the signpost it receives the post's signal and relays its new location to the control centre when queried by the centre's radio. In some systems the vehicle location between signposts is calculated using the odometer reading.

Suppliers expect surface users for this system to include: **public services** (i.e., urban transit vehicles, passenger rail - regional and intercity) and **goods movement** (i.e., freight trains)

6.3.7 Radio Frequency (RF) Identification System

The RF Identification system consists of tags (transponders) and readers (interrogators). The system works by having a reader send out a steady radio frequency beam toward a tag. The tag then reflects a signal back to the reader. It is the reflected signal that carries the identification code. The tags are not transmitters and do not radiate signals by themselves. They are either passive or battery powered but do not reflect back an identification signal unless interrogated by a reader. Battery-powered tags stay energized at all times and battery life is not affected by the number of times a tag is read. The tags

** Transport Canada, Facility Engineering and Systems Development Branch
Aviation Group, LORAN-C Coverage in Canada, TP7561E, (No Date).

may be read reliably at distances from inches to more than 60 feet, and under test conditions the tags have been read at more than 200 feet away. The tags have been successfully tested at speeds up to 180 miles per hour without any equipment adjustments. The capability of the system to read tag codes approaches 100 per cent. Errors and misreadings are very rare.

Suppliers expect surface users for this system to include: public services (i.e., urban transit vehicles, passenger rail - regional and intercity) and goods movement (i.e., freight trains)

6.3.8 Advanced Train Control System (ATCS)

ATCS was designed to slow down, speed up or to stop trains according to a plan that will eliminate prolonged delays and increase operating efficiency and subsequently to increase capacity on all rail lines. Currently, Union Pacific (UP) and Burlington Northern are actively engaged in testing their own versions of ATCS. UP is using passive transponders embedded in the track beds to provide precise location data. This data is radioed automatically to the dispatching centre where the data is examined and incorporated into the overall scheme of operations. Enroute, train crews enter data regarding pick-up or drop-off of cars into an on-board terminal and this information is automatically recorded by UP's Train Control System for customer car location access and the central ATCS for train-handling adjustments, if warranted.

A North American committee which includes several Canadian rail companies is currently developing ATCS applications for the rail industry.

The proposed North American Advanced Train Control (ATC) system consists of five upward compatible levels of sophistication, superimposed upon a centrally dispatched manual block system. The levels are as follows:

<u>ATC Level</u>	<u>Features</u>
Base Level:	Centrally dispatched manual block system via voice mobile radio.
Level 10:	Base Level plus a computer to perform conflict checking and to generate train sheets and routine reports (equivalent to a computer aided manual block system).
Level 20:	Level 10 plus data messages being relayed between control centre and locomotives (and other equipped track units) via data mobile radio, with modern cab displays and no track-side signals.
Level 30:	Level 20 plus train position determined by transponders, and train position and speed advised automatically to the control centre.
Level 40:	Level 30 plus presence detection within stations added, plus locomotive control of switches.
Level 50:	Level 40 plus presence detection and broken rail detection on main lines.

6.3.9 Mobile Emergency Tracking System (METS)

METS is a central station, mapping and vehicle location/management system. The METS TRACKER unit is interfaced to a radio. Signals are transmitted over the radio network, using digital data signals via antennas, to the radio base station, and then interfaced with the METS Central Station Control. METS changes the signals to give a visual presentation of the situation. Additional options include routing/dispatch, and address matching capabilities.

6.3.10 Cellular

The use of cellular technology for vehicle positioning could theoretically be done using a measured phase shift of distance. However, to actually locate a vehicle would be very difficult and imprecise because of the multipathing effect from the multiple signals bouncing off various objects. Digital cellular would not be particularly better for increasing locating capability. However, the technology has the capability of locating a vehicle within a cell which has a range of five square miles. Loose resolution display could be available and not very expensive. Due to the lack of coordination in the U.S. amongst the many companies providing cellular service, extensive coverage in the U.S. is very poor.

The cellular technology may become a solution in the future. The problem of locational inaccuracy in an urban core associated with cellular technology is presently under study. One approach is to document the behaviour of travelling electromagnetic signals and to introduce a correction algorithm in the software. This software would be updated periodically to take into account changes in the skyline of a given city.

6.3.11 Line 10 Television System

The Line 10 Television system radiolocation technology is based on the fact that the transmission of the 10th line of every frame of all television transmissions is very precisely coordinated to a central (very precise) cesium clock. Theoretically, this means that if a receiver is calibrated to receive 3 TV stations with known transmitter locations, it is possible for the on-board computer to calculate its position by triangulation (calculating distances from time delays in reception of 10th line) given that precisely same transmission time.

The Line 10 Television system approach is not being used for radiolocation purposes (and there are no plans to actually do so) because of very severe multipath problems.

6.3.12 VOR, VOR/DME, TACAN

(Very High Frequency Omnidirectional Range (VOR), Distance Measuring Equipment (DME) and Tactical Air Navigation (TACAN). These three systems provide the basic guidance for enroute air navigation in the Canada and the U.S. VOR provides a bearing from an aircraft to the VOR transmitter. DME provides a measurement of distance from the aircraft to the DME ground station. TACAN is a military UHF radionavigation system which provides a pilot with relative bearing and distance to a ground-based beacon. These three systems are based on line of sight which provides good coverage for aviation operations. However, line of sight coverage for land applications have obvious limitations due to terrain and urban construction obstacles.

6.4 PRESENT SATELLITE BASED RADIONAVIGATION SYSTEMS

6.4.1 Radio determination Satellite Services (RDSS)

Radio determination Satellite Service (RDSS) is a set of radio ranging, communication and computational techniques that enable users with a suitable transceiver to determine their geographical position and to relay this and other information via satellite through a ground based control centre. RDSS employs geosynchronous satellites to serve a wide geographic area, such as all of Canada. The system control centre transmits an interrogation signal many times per second to one of the geosynchronous satellites. This satellite retransmits the signal at a second frequency to a desired coverage area on the surface of the earth. Suitable transceivers receive the signals and transmit a response at a third frequency back to the satellite. The transceiver may receive a position determination or message or send a message to a designated ground location or to another specified transceiver.

The responses to individual transceivers are received by all three geosynchronous satellites and are retransmitted at a fourth frequency to the system control centre. By determining the time taken for the signals to travel via each satellite, a computer in the control centre can determine the distances travelled by the signals and hence calculate the position of the transceiver. The position coordinates of the transceivers are inserted into the continuous interrogation signal sent to one of the three satellites for retransmission to the transceivers. Individual interrogation signals, those coordinates that are addressed to their identification code, the transceiver then sends a further response to provide the system control centre with an acknowledgement that it has received the position coordinates.

The mentioned transmission paths are also used to send non-positioning alpha-numeric information. The amount of such information that may be sent is a variable system parameter. For example, a user may want to have either his position or an unrelated message sent to another transceiver. The user would then enter the intended destination transceiver's identification code prior to commanding his transceiver to respond to the interrogation signal.

Two types of RDSS systems have been identified; those using wideband ranging and those using narrowband ranging. Wideband ranging is used by GEOSTAR (see 3.2.14), Mobile Communications of America and McCaw Communications. Narrow band ranging is typically used in mobile satellite systems and is significantly less precise than wideband ranging methods used in RDSS systems. Accuracy in the order of .1 miles has been demonstrated. Examples of the latter include Omnimet, Mobilesat and Skylink. RDSS systems have been interfaced successfully with LORAN-C and Omega.

The expected surface users for RDSS include: **public services** (i.e., rail, emergency vehicles - security); **goods movement** (i.e., long haul intercity trucks and trailers); **military** (i.e., truck); **private** (i.e., passenger vehicle); and **resource management**.

6.4.2 GEOSTAR

GEOSTAR is a U.S. commercial satellite based communication and wideband ranging system servicing a wide variety of users with position locating requirements in the 100 metres range. The system will be composed of three geostationary satellites relaying information between a control centre and user terminals (transceivers). The process commences when the base station sends out an interrogation code that addresses a message to one or a group of vehicles, in addition to a digital notation indicating the time the message (signal) was sent. One satellite relays the signal to the vehicle's transceiver where it is transmitted to both satellites which, in turn, relay it back to the ground station.

Taking into consideration the original time of notation, the base-station computer calculates the time it took the vehicle's retransmission to reach the separate satellites. The computer can determine the vehicle's distance from the pinpoints and therefore locate the vehicle based on the knowledge of where the satellites are located. Digital map data is used by the computer to convert location coordinates into actual location of the vehicle and the computer transmits this data to the terminal. The major advantage of GEOSTAR compared with other satellite-based systems is that no processing to calculate position takes place in the vehicle itself. This means that the vehicle receiver can be very simple and low cost. This system is currently being used by Frederick Transport in conjunction with LORAN-C.

6.4.3 SARSAT/COSPAS

SARSAT/COSPAS utilizes a configuration of two transponders on polar orbiting weather satellites, one of which is American and the other Russian known as GOES. Signals are picked up from Emergency Locator Transmitters (ELT) and retransmitted to ground stations which are capable of obtaining a fix within 15 minutes to four miles. The fix interval can be up to 12 hours.

6.4.4 Other Systems

6.4.4.1 Fleet-trak

Fleet-trak is an integrated system which operates over existing communications systems including UHF, VHF, HF, cellular telephone, and satellite links. It is designed to provide the dispatcher and fleet manager with up-to-minute information on vehicle location as well as operator and vehicle performance. Engine and vehicle performance data is stored in environmentally rugged solid state memory.

Fleet-trak can utilize any of a number of navigation systems including LORAN-C, VLF-Omega, Decca, and Inertial. Mobile units with integral LORAN-C receivers and data radios are available.

The expected surface users for this system include all public services, goods movement, and military (truck and off road). Specific applications for special features include:

- o **law enforcement** - the Silent Alarm feature gives the dispatcher an immediate alert of a unit in trouble and indicates which units are in a position to respond quickly; a list of closest units to a given location provides for fast response to emergencies;
- o **transit** - enables close monitoring of schedules and facilitates flex routing; Silent Alarm feature allows for instant response to an on-board emergency;
- o **executive security** - VIP vehicles are tracked continuously with a foot switch always available to signal an emergency; security escorts can be coordinated without voice transmissions being intercepted;
- o **general emergency services** - silent emergency signals activate an audible alarm at the dispatcher's console, changes the vehicle's ID to blinking red on the map and lists the five closest vehicles of the same type; predefined search patterns are also available to facilitate search and rescue operations;

- o **emergency medical services** - rapid dispatch of the closest vehicles to the scene of an accident ; medical data can be transmitted over data link to the receiving hospital in preparation for the patients arrival; and
- o **military** - remote monitoring of vehicles in field exercises with a wide screen situation display enables real-time critiques of operations; portable base station lets the field commander view vehicle movements; border patrol or customs operations can be coordinated from a central location with the unique two-way data link feature.

6.4.5 Other Non-Surface Navigation Systems

Other navigation and communications systems examined which are not used for land applications include the following:

- a) **TRANSIT** is a Navy Navigation Satellite System (NNSS). It is a satellite-based positioning system which provides submarines, surface ships, and a few special aircraft with an accurate two-dimensional capability the system has been used very successfully for shipborne navigation in Canada since the early 1970's. The TRANSIT system currently consists of approximately seven low-altitude satellites in near polar orbits, ground-based monitor stations to track the satellites, and injection facilities to update satellite orbital parameters. Transit will be phased out on implementation of the Global Positioning System (GPS).

The expected surface users for this system include:

- o **public service** (i.e., emergency vehicles - security);
- o **military** (all vehicles);
- o **private** (i.e., offroad, portable/personal); and
- o **surveying**.

Tsikada is the U.S.S.R version of TRANSIT and has been operational since the early 1970s. The system uses 4-5 satellites in near circular orbits at an altitude of 1000 km and inclined 83 degrees to the Equator. It provides global coverage. Actual position accuracy is about 0.3-0.4 mile. Tsikada is used for marine navigation.

- b) The **ARGOS** system offers capabilities for the satellite-based location of fixed and moving devices for the purpose of collecting environmental data. The system is the result of cooperative agreements between the Centre National d'Etudes Epatiales (CNES, France), the National Aeronautics and Space Administration (NASA, US) and the National Oceanic and Atmospheric Administration (NOAA, US). Every 100 minutes, a space craft passes overhead, receives and records data and retransmits same when passing over an Argos Telemetry station. Location of terminals is determined through analysis of doppler effects. Argos data from other data received from the weather satellite downlink, with CNES is responsible for processing and distributing ARGOS data. The consortium agree on authorization of user access to the system through control user terminal devices called Platform Transmitting Terminals (PTT).

Most PTTs are in maritime applications, such as floating buoys and shipboard platforms. Some are land PTTs such as remote meteorological stations. Less common are polar ice buoys, atmospheric balloons and animal tracking platforms.

6.5 FUTURE SYSTEMS

6.5.1 NAVSTAR Global Positioning System (GPS)

NAVSTAR GPS is a U.S. military space-based radionavigation system providing users with navigation and positions in three dimensions, velocity in three dimensions, and highly accurate time. The system has three major segments: space, control, and user. The space segment will consist of 24 satellites in six orbital planes. The satellites operate in near-circular orbits at an inclination angle of 55 degrees and a twelve hour period. The GPS concept is predicated on accurate and continuous knowledge of the spatial position of each satellite with respect to time and distance from a transmitting satellite to the user. The GPS receiver automatically selects appropriate signals from three to seven of the best satellites in view and resolves time-of-arrival difference quantities to obtain distance between user and satellites to establish the user's position in relation to the satellite system. A time correction factor then relates the satellite system to earth coordinates. Satellite based navigation systems including GPS have suffered from gaps in coverage and problems in densely built-up areas (the so called "urban canyon effect"). Furthermore, these problems intensify in Northern areas.

Although the U.S. DOD has not authorized the use of GPS military ("PPS" code) signals in space it has guaranteed access by civilians, worldwide to the Standard Positioning System (SPS) which is based on the C/A code (Course/Acquisition). Several commercial companies are in fact developing, manufacturing, and selling GPS receivers for use with the GPS test constellation. However, until the U.S. DOD declares GPS operational, they have stated that the use of the system will be at the user's risk. An additional factor is the question on the use of the Precise Positioning Service (PPS). The NAVSTAR GPS constellation is expected to become operational in 1992. Differential GPS has been undergoing successful tests in many countries, including Canada.

A Radio Technical Commission Maritime Special Committee (SC-104) developed a concept and techniques for maritime Differential GPS. The first version of standards are currently available. The same standards are applicable for land surface use.

Currently Differential GPS is in research, engineering, development, and test for almost all modes and phases of navigation. The Research and Special Programs Administration of the U.S. Department of Transportation is closely monitoring Differential GPS technology development and system performance for surface navigation use.

The expected surface users for this system include:

- o **public services** (i.e., intercity buses - tour/charter, passenger rail - regional and intercity, emergency vehicles - police & security, ambulance and fire);
- o **goods movement** (i.e., courier vehicles, pick-up and delivery trucks, freight trains, and other trucks and vehicles);
- o **military** (i.e., truck, car, off road, portable/personal);
- o **surveying**;
- o **resource management**; and
- o **agriculture** (i.e., pick-up, off-road tractor/combines).

If the ACS is developed to provide real time differential positioning, at the 1 to 5 metres accuracy level, all users will be affected.

6.5.2 Autoguide

The U.K. Autoguide was developed in 1986 by the U.K. Department of Transport. "Autoguide is a system for helping drivers find their way through primary road network. A route computer is mounted in the vehicle and the driver enters the destination. Either visually or using synthesized speech, the computer then gives easy-to-follow instructions during the journey".^{***} The system uses beacons which are small computers and it stores the electronic signpost information to determine positioning.

6.5.3 ALI-SCOUT

ALI-SCOUT is a joint effort of the Federal Republic of Germany, Siemens, Volkswagen, Blaupunkt, and others. The system combines a dead reckoning navigation with a two-way infrared communications link between the vehicle and the roadside. A digitally encoded map of the entire surrounding area is fed to each vehicle as it passes a beacon, including traffic dependent guidance recommendations. Knowing the position of the car and the driver's destination, the vehicle navigation system can then guide the driver along the most expedient route.

6.5.4 Automatic Route Control System

Automatic Route Control System (ARCS) is a fleet management system applied to vehicular navigation. ARCS provides command and control functions in addition to real-time route guidance over programmed newspaper delivery routes. "The routes were programmed on tape cartridges in the form of digital maps which include the location of each individual street address. The route data tapes could be prepared from central computer files, or by driving a route with an equipped vehicle to "record" the route."^{****}

6.5.5 Mobile Satellite Service and INMARSAT Standard-C

The Mobile Satellite Service (MSS) is a communications capability wherein bandwidth is divided by frequency in pairs of channels which are, in turn, allocated in pairs to mobile communicators. These channels are normally divided in bandwidths of from 5 KHz to 50 KHz depending on considerations, and where the channels are also used to determine position then the mobile satellite service is also providing radiodetermination capability. If the channels are used to relay positioning information derived in some other manner then the MSS is not on RDSS.

The INMARSAT system is the standard maritime mobile satellite service, but also has been considered for aeronautical and land mobile communications. A bandwidth is divided by frequency into pairs of channels which are in turn allocated in pairs to mobile communications. If these channels are also used to derive positioning information, then

^{***} R. L. French; "The Evolving Roles of Vehicular Navigation"; R. L. French Associates; Fort Worth, Texas; 1987

^{****} Robert L. French, "The Evolving Roles of Vehicular Navigation", R.L. French and Associates, Fort Worth, Texas, June 1987.

there is also a radiodetermination capability. Narrow band ranging via continuous audio-frequency modulation-tone ranging. Less accurate than wide band ranging methods but demonstrated accuracy to 0.1 mile. A digital tone ranging technique has been developed in Japan to obtain measured ranging via satellite.

6.5.5.1 ETS V/AMEX

ETS V/AMEX is similar to Inmarsat. It is only in the proposal stage.

6.5.6 Mobile Satellite (MSAT) Program

Two-way mobile radio and telephone service available to Canadians using a satellite as a relay station in space. Typical applications for the service in the area of public safety include police, ambulance, search and rescue, air traffic control and safety services, safety communications for the trucking industry, operational communications for large construction projects in remote areas, and in support of resource development activities in forestry, oil exploration and mineral exploration.

Two 4 MHz bands were allocated to maritime mobile satellite service and land mobile satellite service. The system will use one Canadian satellite in the initial system using one or more U.S. satellites for back-up. Satellite coverage under consideration for the first-generation system covering Canada and the U.S. with a five metre spacecraft antenna or possibly a four-beam system requiring a nine metre antenna, allowing 4/3 system frequency reuse. The Canadian system has a capacity of 400 UHF channels. The first-generation Canadian MSAT system will be comprised of one spacecraft, a communications and control station responsible for managing the flow of communications through the MSAT system, gateway stations for connection to the public telephone network and several hundred base stations to funnel traffic to and from mobile radios. The first-generation system will be able to accommodate up to 60,000 mobile units. The forecasted selling price of the first-generation UHF mobile terminal including the antenna will be \$3,500-4,500 or less.

6.5.7 NAVSAT

NAVSAT is a positioning system proposed by the European Space Agency. It is similar to GPS but with 12 satellites spread over six twelve hour highly eccentric orbits inclined at 63.5 degrees over the equator and six equispaced geosynchronous satellites.

6.5.8 AVSAT

AVSAT is a worldwide satellite based communications system by Aeronautical Radio Inc. (ARINC) for global aircraft communications. The system has potential for navigation for land surface users.

6.5.9 Fleetstar Service

The initial offering of Fleetstar will be LORAN-C position from user terminals sent to Telesat control centre via Inmarsat satellites and transoceanic fibre optic cable using Standard-C communications system which facilitates modern two-way satellite communications. Standard-C uses digital transmission techniques for both signalling and message data. All message data and signalling information is transmitted in packet form.

Good error correction performance at low carrier to noise densities is achieved. (See section 6.3.5).

6.5.10 Other Systems

Navigation and communication systems examined which are not currently used for land applications are as follows:

- a) The Chaika system is a low-frequency pulse-phase which is similar to LORAN-C which operates in the outlying seas and has a coverage of 1000 miles in Russian waters. A Russian and American effort is being made to use land based stations of the Chaika and LORAN-C systems, in order to eliminate mutual interference, to extend the coverage and to reduce costs of their maintenance and development.
- b) The GLONASS is a Russian developed positioning system which is similar to GPS and is in the trial phase of constellation orbiting.

6.6 SYSTEMS CHARACTERISTICS SUMMARY

The information included in Figure 6.1 is solely intended as a technical summary supplement, it is not a necessary reading for those unfamiliar with the technical aspects of radionavigation.

Figure 6.1 summarizes the technical characteristics of the systems reviewed in the preceding section. The table was put together on the basis of information contained in technical documents supplied by systems proponents and receiver manufacturers which were obtained in the course of the supplier survey.

Further details on specific systems are contained in Appendix B. This material is based on responses received in the supplier survey.

FIGURE 26: SYSTEM CHARACTERISTICS

CHARACTERISTICS										
SYSTEMS	SIGNAL	ACCURACY	AVAILABILITY	COVERAGE	RELIABILITY	PIX RATE	PIX DIMENSIONS	CAPACITY	AMBIGUITY	INTERFERENCE
A. Loran-C	pulsed, hyperbolic system, 90 to 110 kHz	0.25 nm or better, repeatable and relative accuracy usually 18 to 90 m.	>99.9%	300,000 sq. mi. more or less	normally >99.9% triad >99.7%	10 to 20/min.	≥2 LOPs	Unlim.	Yes, but easily resolved	Yes, constant monitoring
B. Differential Loran-C	As above with digital correction signal	5 to 20 m	>99%	Selected Continental US Areas *	>99%	10 min.	2 dim.	Unlim.	No	As above
C. Omega	cw trans. from pairs of 8 stations, 10.2 kHz, 11.33 kHz, 13.6 kHz, 11.05 kHz.	2 to 4 nm	>99% >95% for 3 stations	worldwide	99% single station 95% for 3 stations	once/10 sec.	≥2 LOPs	Unlim.	Yes, DR plot or other means must be carefully maintained.	Yes, trans. monitored constantly.
D. Differential Omega	10-14 kHz with digital correction signal	1 nm at 500 nm	>98% >94% for 3 stations	100-200 nm to ground	>98% >94% for 3 stations	NA	2 dim.	NA	No	NA
E. Radiobeacons	190-415 kHz 510-535 kHz CCW or MCW	±3 to ±10 deg	>99%	dependent on power transmitted	99%	1 LOP during trans.	1 LOP Fix with 22 beacons.	Unlim.	Yes, reciprocal bearing. Resolve or use sense antennae.	Yes, shuts down on out-of-tolerance condition.
F. GPS	satellites continuously transmit a composite spread signal at 1227.6 & 1575.42 MHz.	Precision (P) signal 20 m. S Code C/A Code. 50 m.	Nearing 100% with satellites in view	Global	98%	Cont.	3-dim. pos. & velocity, accurate time info.	Unlim.	No	Yes, users are notified of failures.
G. Differential GPS		P Code 5 m C/A Code 8 m	NA	NA	NA	NA	NA	NA	NA	NA
H. Transit	Satellite broadcast of ephemeris info on 150 & 400 MHz.	Single freq. rec. is 500 m. Dual freq. rec. is 25 m.	>99%	Global but not continuous.	>99%	Varies with latitude.	2-dim. fix.	Unlim.	No	Yes, alerting message sent when satellite signal is out-of-tolerance.

NA - not available

FIGURE 26: SYSTEM CHARACTERISTICS (Continued)

SYSTEMS	CHARACTERISTICS									
	SIGNAL	ACCURACY	AVAILABILITY	COVERAGE	RELIABILITY	FIX RATE	FIX DIMENSIONS	CAPACITY	AMBIGUITY	INTENSITY
I. Dead Reckoning	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J. Gyroscopic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K. Doppler Radar	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
L. Gyro-Magnetic Compass	Stabilized magnetic sensor	.75 degrees in slaved mode with a 2 per hour drift	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
M. Decca	Hyperbolic 70-90 kHz 110-130 kHz	function of geometry between 500 feet and 3nm	N/A	250 nm-300 nm	100%	N/A	N/A	N/A	N/A	N/A
N. VOR	108 to 118 MHz	2 sigma $\pm$ 1.4 degree predictable error $\pm$ 0.35 relative error $\pm$	Near 100%	surface: line of sight limitations 30 miles	Near 100%	Continuous	Magnetic bearing to VOR station and deviation from a selected course in degrees.	Unlimited	No	Yes. Removes signal from use within 10 seconds of out-of-tolerance condition
O. DME	Paired pulsed signals 960 to 1213 MHz	2 sigma predictable error $\pm$ 0.1 nm relative Error emanates from receiver and flight technical error	Near 100%	Same as VOR	Near 100%	Continuous	Slant range to station in nm.	Limited 110 interrogators	No	Yes Same as VOR
P. TACAN	pulsed 960 to 1215 MHz	1.0 degree 4.5 degree for 15 Hz element	>99%	same as VOR	>99%	Continuous	2 distance & bearing	110 for distance Unlimited azimuth	No in range slight potential at multiples of 40 deg.	Yes transmitters monitored constantly

NA - not available

FIGURE 26: SYSTEM CHARACTERISTICS (Continued)

SYSTEMS	CHARACTERISTICS									
	SIGNAL	ACCURACY	AVAILABILITY	COVERAGE	RELIABILITY	FIX RATE	FIX DIMENSIONS	CAPACITY	AMBIGUITY	INTERFERENCE
Q. ATCS	N/A	15-65 nm	>99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
R. Sign Post	N/A	0-5 metres	>99%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
S. ARGOS	N/A	401.650 MHz position determined by Doppler effect.	500 m to 50,000 m	Avail during satellite passes over IRL	Worldwide	>101 minutes	Position	Limited	Yes, can be resolved with knowledge of previous position of range of speeds possible	No
T. RDSS-GEOSTAR	Control center to satellite 6541 MHz Sat to Cont 5117-5183 MHz Sat to User terminal 2484-2500 MHz User terminal to Sat 1610-1626 MHz	Altitude known 12 m Altitude calculated 30-50m	Nearing 100%	Continental. No coverage on the north side of shielded buildings at mid to highest latitudes in northern hemisphere.	Essentially continuous but will reduce when/if system approaches saturation	N/A	3 dim. positioning and other services	Limited to 100X10^6 transactions per hour	No, when 3 satellites functioning	N/A
U. MSAT	806-890 MHz	N/A	100%	National 200 mi offshore coverage	98 %	N/A	N/A	N/A	N/A	N/A
V. Cellular	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
W. INMARSAT	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

N/A - not available

N/A - not available

**APPENDIX A: SURVEY OF SUPPLIERS OF RADIO
LOCATION/NAVIGATION EQUIPMENT**

APPENDIX A

SURVEY OF SUPPLIERS OF RADIO LOCATION/NAVIGATION EQUIPMENT

INTRODUCTION

The survey of suppliers of radio location and navigation equipment provided a range of information on potential or existing radionavigation products applicable to surface use. The data related to such areas as: type of equipment offered; the company's actual and/or planned use of the product; expected installation base; coverage; current and future market information; and specific characteristics, functions and capabilities of the product. The equipment and systems covered by the survey included: satellite based systems, LORAN-C, Omega, proximity devices, dead reckoning and full location and performance monitoring systems utilizing a variety of positioning techniques. The following section summarizes product information which will be useful in determining the match between the requirements of the users and the relevant radio location and navigation equipment.

Equipment coverages, accuracies, update rates, and functions shown are those claimed by manufacturers or distributors responding to the survey and as such have not been tested or validated under this task. The higher accuracies claimed are normally the result of the manufacturer feeding a highly calibrated test signal through the processor (simulating a near perfect signal) to arrive at an accuracy for their equipment. However, this does not allow for dilution of signal for various geographic locations.

SATELLITE BASED SYSTEMS

Satellite based systems have recently been serving a multitude of functions since their early years as either communications or surveillance systems. Within the past two decades they have been increasingly used for navigation. Such systems as GEOSTAR not only provide communications links but are also being used for radiodetermination for users that are properly equipped. Satellite systems also have the capability of being used cooperatively with other conventional terrestrial radionavigation systems. Newer systems such as GPS have been designed specifically for precision positioning and navigation. Satellite systems are now easily maintained in precise orbits, provide global coverages mostly on a continuous basis, are highly accurate in terms of positioning and time, and have almost unlimited capacity.

Descriptions of various satellite systems are found in Section 3 of this report.

NAVSTAR GPS Receivers

Current manufactured GPS receivers are portable, integrated systems which are technically (but not necessarily economically) well suited for surface applications. Information concerning GPS receivers were received from Rockwell International, Canadian Marconi Avionics Division, and SURNAV (distributor for Trimble Navigation, TAU Corporation, and Del Norte Technology).

NAVSTAR GPS Receiver Features

- o functions: position of vehicle, route guidance/navigation, tracking and monitoring
- o coverage: continental
- o accuracy: 0-15 metres
- o weight of on-board equipment: 0-2 kilograms
- o update rate: less than one minute
- o primary positioning technique: satellite based

The supplier(s) indicated that approximately seven vehicles are currently using the GPS receiver and four units are currently in service worldwide. The price range quoted per unit is \$50,000 - \$100,000 (US).

Trimble 4000 series (GPS)

The TRIMBLE 4000 series include a variety of integrated, portable systems. The receivers are suitable for all types of vehicles used for public services, goods movement, military, private, surveying, and resource management. The 4000 series offer the following characteristics, functions and capabilities:

- o functions: position determination
- o coverage: continental
- o accuracy: 0-15 metres
- o weight of on-board equipment: 6-10 kilograms
- o update rate: 1-10 seconds

Model Specifications

Following are the descriptions of nine specific systems.

Trimble 4000A GPS Locator is a positioning determining system designed to extract the maximum accuracy from the GPS system. The unit automatically acquires and simultaneously tracks up to five satellites, measures range and range rate, and computes position and velocity. Independent position and velocity computations are computed within one second. It is ideally suited for stationary or moderately dynamic applications on land.

Trimble Navigation 4000SX GPS Surveyor is a low cost GPS receiver built around the 4000A Locator and is especially designed for stationary applications. The 4000SX has the capability to acquire very high (survey level) accuracy data. It can however be used in a mobile environment where it will still yield high accuracy positioning.

4000SX Features

- o allows the operator to record data, for later processing, and simultaneously obtain precise position fixes to ensure the quality of the data being taken
- o can be used in a mobile environment
- o simple post processing yielding high accuracy

Trimble Navigation 4000SD Surveyor is a dual-frequency receiver built around the 4000SX. It adds the capability of acquiring a second frequency to eliminate ionospheric effects.

Trimble Navigation 4000SL Surveyor is a lightweight, backpackable GPS system that can be operated in any environmental extreme. It consists of a receiver/processor in a field case connected to an antenna/preamplifier with tripod mounting.

4000SL Surveyor Features

- o pre-programmable in the office for ease of operator use while in the field
- o data logging is accomplished on an internal 1 MByte of solid state memory that eliminates the need for less reliable cassette tapes or field computers

Trimble TANS GPS Receiver, GPS Pathfinder, Trimpack

TANS, Pathfinder, and Trimpack are rugged and portable integrated systems that are very well suited to surface applications. These products offer the following functions and capabilities:

- o functions: position, and route guidance/navigation
- o coverage: continental
- o accuracy: 3-25 metres
- o weight of on-board equipment: 0-2 kilograms
- o update rate: 1-10 seconds

- o primary positioning technique: satellite based
- o secondary positioning technique: LORAN-C
- o future (1992-1995): independent vehicle location and tracking provided worldwide with 24 hour coverage

According to the supplier, 60 vehicles (Canada - 10, U.S.A. - 50) are currently using this product and approximately 100 to 1,000 units are in service world-wide. The quoted price range per unit is \$5,000 - \$25,000 (US) with projected sales, cumulative to 1995, expected to be in the 1,000 to 10,000 units range.

Trimble TANS GPS Receiver is a two-channel, GPS Navigation Sensor that receives the L-band, Coarse/Acquisition (lower level accuracy i.e., non-military) code signals broadcast by the NAVSTAR GPS satellites. TANS uses the GPS signals to provide three dimensional positioning, velocity and time. It is intended for applications where size, weight, and power are at a premium.

TANS Features

- o no initialization required
- o automatic satellite selection algorithms
- o no maintenance, high reliability
- o easy integration, interface, and operation
- o accuracy of position: 25 metres
- o update rate: once per second

Trimble GPS Pathfinder is a navigation and position logging system capable of operation in demanding field conditions. It embodies the TANS GPS receiver and includes a control display unit providing user interface and functions that include receiver control and waypoint navigation.

The Pathfinder provides flexibility for various user applications. Accessories allow configurations that include a battery powered, man-portable system and a vehicle-mounted, vehicle-powered system.

Pathfinder Features

- o accuracy: 25 metres
- o software is available which provides display and plotting of recorded data

- o differential processing software is available for applications where increased accuracy is required
- o update rate: once per second

Trimble Trimpack is a small, lightweight, self contained, hand-held GPS navigator with a 2-channel GPS receiver as its source of accurate position and time. Its rugged, sealed construction is designed for field operations and rough handling. Trimpack is applicable to low dynamic vehicle navigation such as people and land vehicles.

Trimpack Features

- o No formal operator training required
- o Automatic mode selection
- o high reliability, Mean Time Between Failures is in excess of 10,000 hours
- o compact and lightweight
- o accuracy: 25 metres

GPS SYSTEM CHARACTERISTICS		GPS RECEIVER CHARACTERISTICS
Coverage	Worldwide	
Availability	Expected 100%	
Accuracy	17.8 metres	0-25 metres
Update Rate	Continuous	once per second

As can be seen from the above table, GPS based receiver covers the range offered by the system in terms of accuracy while remaining in the once per minute to once per second update range. None of the receivers appears to be configured expressly for use in an urban environment and receiver prices are still out of range for routine use in surface applications.

TRANSIT Satellite Receiver

The Transit receiver comes in three models that are applicable to surface use. However, due to the high frequency characteristics of this receiver, the expected user base for surface mode would be limited to open areas away from interfering obstacles such as buildings.

Transit Receiver Features

- o functions: position, route guidance/navigation, and tracking
- o coverage: continental
- o accuracy: 65-200 metres
- o weight of on-board equipment: 6-10 kilograms
- o update rate: one second
- o primary positioning technique: satellite based

The supplier indicated that currently 50 vehicles are using this product worldwide. The quoted price range per unit is \$2,000 - \$5,000 (US). Projected sales, cumulative to 1995 are expected to be in the range of 1,000 to 10,000 units.

TRANSIT SYSTEM CHARACTERISTICS		TRANSIT RECEIVER CHARACTERISTICS
Coverage	Worldwide Non-Continuous	
Availability	99%	
Accuracy	25 metres Dual Freq. 500 metres Single Freq.	65-200 metres
Update Rate	Varies with Latitude	one second

OMEGA Navigation Receivers

A description of the OMEGA system can be found in Section 3.3.3. Tracor was the only company who makes Omega navigation receivers to respond to the questionnaire.

Tracor Omega Navigator

Tracor Omega Navigator is the smaller of two models offered by the supplier; the other is the Tracor Automatic Omega II. Given that the smaller, less expensive model is more popular and more appropriate for surface applications, data was

provided for this model only. The Tracor Omega Navigator is an integrated system operating at low frequency. However, it is subject to interference and not suitable in urban areas. It is most suitable for applications in open areas.

The Tracor Omega Navigator is said to be favoured by surface users in many remote areas all over the world. It is particularly attractive because it provides continuous signals without speed or heading input.

Tracor Omega Navigator Features

- o functions: position and route guidance/navigation
- o coverage: continental
- o accuracy: 1 kilometer (day), 1.5-2 kilometers (night)
- o weight of on-board equipment: 6-10 kilograms
- o update rate: 1-15 minutes
- o primary positioning technique: Omega/VLF.

The supplier indicated that approximately 100 vehicles are using the Omega Navigator worldwide. The quoted price range per unit is \$2,000 - 5,000 (US). Sales projections, cumulative to 1995, is 1,000 to 10,000 units.

OMEGA SYSTEM CHARACTERISTICS		OMEGA RECEIVER CHARACTERISTICS
Coverage	Worldwide Continuous	
Availability	99% +	
Accuracy	3.7 to 7.4 kilometres	1 kilometre (day) 1.5 to 2 kilometres (night)
Update Rate continuous	once every 10 seconds	1 to 15 minutes

LORAN-C

Suppliers of LORAN-C equipment are primarily suppliers of receiver sensors to systems manufacturers. Data was provided on two LORAN-C receiver models. Suppliers who submitted information regarding these models include: Micrologic Avionics Inc., Advanced Navigation Inc., Terra Corp., ARNAV Systems, and NARCO Avionics. A detailed description of LORAN-C can be found in Section 3.3.5.

LORAN-C Receiver Sensor

The LORAN-C receiver is an integrated system which is well suited for surface use.

LORAN-C Receiver Features

- o functions: position, tracking, and monitoring
- o coverage continental
- o accuracy 65-200 metres
- o weight of on-board equipment: 0-2 kilograms
- o update rate: less than one minute
- o primary positioning technique: LORAN-C

Advanced Nav LORAN-C Receiver Sensor

ANI-5306 LORAN-C Receiver Sensor is a low cost integrated system intended for surface applications.

ANI-5306 Features

- o functions: position, tracking, and monitoring
- o coverage: continental
- o accuracy: 200-1,000 metres
- o weight of on-board equipment: 0-2 kilograms
- o update rate: less than one minute
- o primary positioning technique: LORAN-C

The supplier indicated that currently approximately 1,000 vehicles are using the product in the U.S. and that 10,000 units are in service world-wide. The quoted price range per unit is \$200 - \$499 (US) and the cumulative sales projection to 1995 is 100,000.

LORAN-C SYSTEM CHARACTERISTICS		LORAN-C RECEIVER CHARACTERISTICS
Coverage	Continental	
Availability	99% +	
Accuracy	460 metres	200 to 1,000 metres
Update Rate	10 to 20 minutes	< one minute

FULL LOCATION AND PERFORMANCE MONITORING SYSTEMS

Radiodetermination Satellite Systems (RDSS)

RDSS is an integrated communication system which uses the federal government's LORAN-C navigation network, GEOSTAR satellite relays and centralized earth station, a ground link to the operations centre and computerized software. The RDSS is extremely suitable for surface applications particularly for long-haul truck communications, tracking and scheduling. More details concerning RDSS can be found in Section 6.4.1. Information concerning full location and performance monitoring systems was received from: Sony Corporation of America, and SEL Division of Alcatel Canada Inc.

Sony Wayfarer

Wayfarer Mobile Communication Unit is a Radiodetermination Satellite System utilizing LORAN-C as its primary positioning technique and GEOSTAR as its communications link. The unit includes a LORAN-C Antenna, Main Unit, Keyboard/Display and Transmit Antenna. The main unit, which contains all the positioning, transmitting, and computing electronics, is a "black box" smaller than a lunch pail. It is made from corrosion resistant materials which provide protection against exhaust gases, wind-blown dust and other environmental conditions.

RDSS Wayfarer Features

- o functions: position, dispatching, route guidance and navigation, tracking, monitoring and communications to and from the mobile unit
- o coverage: continental
- o accuracy: 200-1,000 metres

- o tracking velocity: 160 kilometres/hour
- o weight: 6-10 kilograms
- o update rate: 1-15 per minute
- o primary positioning technique: LORAN-C
- o secondary positioning technique: satellite (by 1992)
- o transmits position and sensor information (e.g., engine overheat, oil low, refer temperature too high, burglar alarm) automatically
- o transmits automatic hour-by-hour positioning reports
- o has the capacity to track and receive messages from hundreds of thousands of vehicles
- o tracking a fleet on a computerized electronic atlas allows analysis of driver hours, load, type of equipment, vehicle performance, and availability of trucks and also permits re-creation of vehicle routes
- o permits driver to relay ETA, LOAD STATUS, WILL CALL, ARRIVED/DEPARTED, and emergency information (e.g., break-ins, breakdowns, incidents, and accidents)

The supplier indicated that approximately 300 vehicles, primarily trucks, are currently using the equipment in Canada and the U.S.A. Furthermore, there are currently 1,000 units in service world-wide. The quoted price range per unit is \$2,000 - \$5,000 (US).

Fleet-trak Vehicle Management Systems

Fleet-trak is an integrated system which operates over existing communications systems including UHF, VHF, HF cellular telephone, and satellite links. It is designed to provide the dispatcher and fleet manager with up-to-the-minute information on vehicle location as well as operator and vehicle performance. Engine and vehicle performance data is stored in environmentally rugged solid state memory. Fleet track can utilize any of a number of positioning/navigation systems including LORAN-C, Omega, Decca and Inertial systems. Data concerning Fleet-track Vehicle Management Systems was received from Offshore Navigation Inc. This system is available in several configurations including:

- o vehicle location only;
- o on-board engine monitoring and data storage; and
- o automatic reporting of both location and engine performance data.

Fleet-trak Features

- o coverage: continental
- o weight of on-board equipment: 6-10 kilograms
- o update rate: less than 1 minute
- o a full two-way data capability using optional keyboard/display units in the vehicles
- o continuous information concerning the location and status of vehicle which is updated every time a report is received from that vehicle
- o accommodates several predefined submaps in addition to the overall map which allows the display of any area in any detail desired (e.g., up to three layers of highways/streets can be presented on the same map)
- o separate terminal screen provides text information including identification, status, location relative to reference points, and lists closest vehicles or objects
- o four types of vehicles can be tracked simultaneously
- o a performance monitoring system monitors the operation of the fleet in real-time and transmits the data to the central computer, or stores the data onboard for processing at a later time. In addition to revolutions per minute, road speed, and fuel flow, it records additional parameters including manifold pressure, several temperatures, and residual oxygen as well as brake applications/pressure
- o data can be played back by removing the storage cartridge and placing it in a reader at the central station or at remote sites connected with a phone line
- o at the central computer, the data is compared to predefined performance and engine "maps" with out-of-tolerance conditions brought to the attention of the operator. The maps are defined for each engine in a given application
- o data is presented graphically and a number of text reports can be generated for specific fleets. Typical reports for over-the-road trucks include fleet status, operator performance, vehicle performance, event report, fuel consumption, and tax report
- o identifies vehicle and engine systems performance that is out of specification and provides intelligence diagnostics of the probable cause

According to supplier information, there are approximately 1,000 units currently in service worldwide. The quoted price range per unit is \$1,000 - \$1,999 (US)

RDSS SYSTEM CHARACTERISTICS		RDSS RECEIVER CHARACTERISTICS
Coverage	Continental, No coverage on the north side of shielded buildings at mid to highest latitudes in northern hemisphere	
Availability	tied to availability of selected location/navigation systems.	
Accuracy	460 metres	200 to 1000 metres
Update Rate	10 to 20 minutes	< one minute

DEAD RECKONING AND PROXIMITY DEVICES

Dead reckoning and proximity devices are described in Sections 3.2.1 and 3.3.6 respectively.

Supplier(s) provided information on the following three integrated systems which are intended for surface use:

SELTRAC - combined wayside R&F and dead reckoning

RSC200 - transponder/dead reckoning

SELTRAIN - radio/dead reckoning/transponder

Systems Features

- o functions: position of vehicle, dispatching, tracking, monitoring, and in some cases route guidance and navigation
- o accuracy: 0-5 metres
- o update rate: less than one minute
- o weight of on-board equipment: 6-60 kilograms, depending on application

- o primary positioning
technique: proximity devices (loop, short range RF, infra red), dead reckoning

Suppliers stated that the major users of these systems are urban transit and mainline railroads. Price range per unit varies depending on system size, complexity and degree of automation.

PROXIMITY & DEAD RECKONING SYSTEM CHARACTERISTICS		PROXIMITY & DEAD RECKONING RECEIVER CHARACTERISTICS
Coverage	Site specific	
Availability	Continuous	
Accuracy	System dependent can be very high.	0 to 5 metres
Update Rate	System dependent	< one minute